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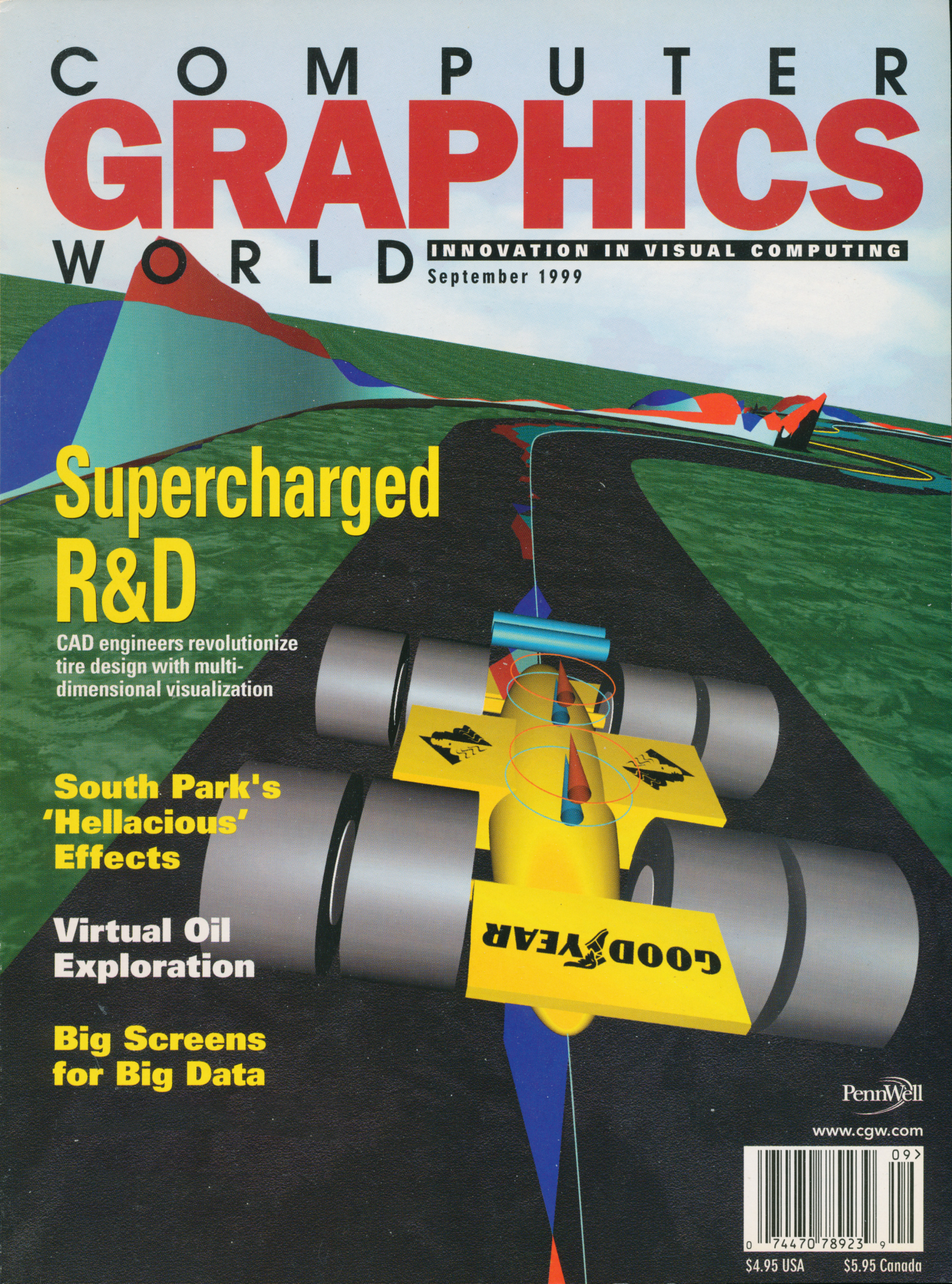
September 1999



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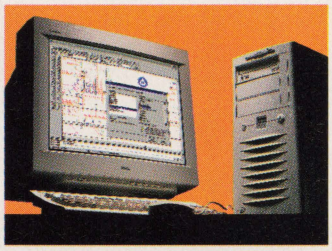

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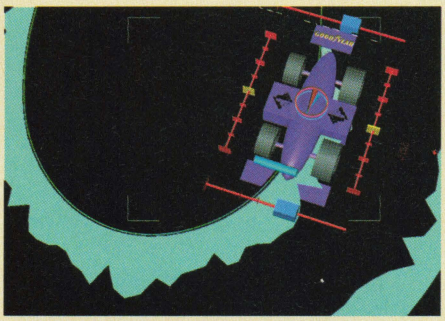

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Oil companies are finding immersive virtual reality to be an invaluable tool in their quest for oil reserves hidden deep within the earth's crust.
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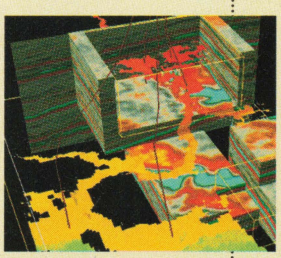

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Large-scale projection displays—from CAVEs to wall-size units—are opening new windows into virtual reality.
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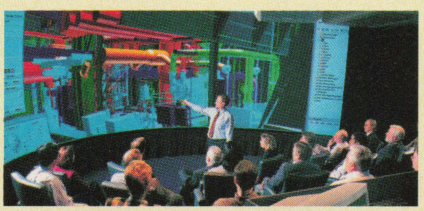

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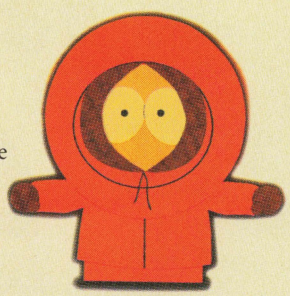
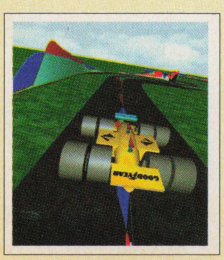
The low-tech look of the movie *South Park: Bigger, Longer & Uncut* owes much to the high-end software and hardware that was used to create it.
• *By Karen Moltenbrey*





ON THE COVER
Using a multisensory interface from MUSE Technologies, Goodyear engineers can visualize and review race-car data such as acceleration, deceleration, and lap distance, and thus ultimately produce better tires. For more information, see "Going the Extra Mile" on page 26.

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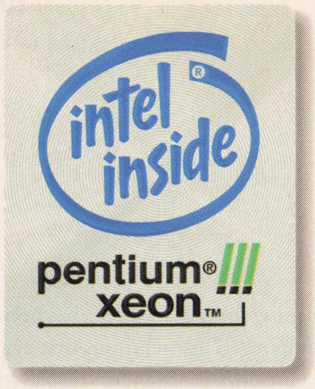

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VR Gets Serious

One of the big surprises in computer graphics during the past few years has been the rapid rise in the use of virtual reality technology. This trend was first evident to me at the 1997 Autofact conference, where dozens of vendors displayed VR systems for manufacturing (see "Editor's Note," December 1997, pg. 6). Now, a new study, "The Visual Simulation/Virtual Reality Systems Market," released in July by Ben Delaney, president of CyberEdge Information Services (www.cyberedge.com), quantifies the expansion of the market as a whole. Citing the results from a survey of hundreds of users of VR systems—ranging from desktop units to theater-scale installations—Delaney estimates that revenues rose last year by 50% (to $18 billion) and will maintain this pace for the next several years.

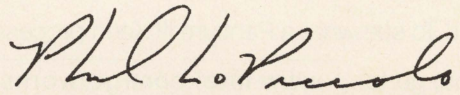
What's spurring such growth? A few years ago, analysts cited figures showing that developers of games and location-based entertainment were bringing the technology, once reserved largely for military training and research, to the masses. But Delaney points out that VR has "moved well beyond the fun and games dominance of a few years ago." In fact, entertainment now ranks last on his report's list of VR's top 15 applications.

What has instead moved rapidly to the forefront are more serious uses of the technology. By far the most popular application, which Delaney determined by tallying the total number of existing users world-wide, has been for virtual prototyping in manufacturing. This is not surprising when you consider that reducing time to market has become the war cry among automotive, aerospace, and other manufacturers, and that visualizing digital models in immersive environments has slashed cycle times at unprecedented rates.

Second on the list of most common VR applications is military training, though training in education, medicine, vehicle operation, and manufacturing now rank among the top uses as well. The third most common use of VR is for military, scientific, and other kinds of research. In fact, this month's feature "Fields of Dreams" (pg. 33) shows how major oil companies are saving untold millions of dollars by using VR environments to visualize 3D seismic data and more accurately pinpoint potential oil reserves prior to drilling.

Despite the obvious benefits the technology has to offer, some serious obstacles must be overcome before the rosy predictions about virtual worlds become reality. Indeed, Delaney's survey revealed tremendous dissatisfaction in current VR systems among users. Ironically, while most of the individual system components—large-screen displays (see "Getting the Big Picture," pg. 41), 3D input devices, head-mounted displays, computer hardware, image generators, tracking systems, modeling software, haptics devices—earned satisfactory ratings, the systems as a whole received extremely poor marks. The chief complaints were that the systems were unreliable, hard to program, expensive, and unsupported by suppliers. "The whole is less than the sum of the parts," Delaney says. And only the largest companies can afford the time, money, and effort to make the pieces work together.

Of course, problems are nothing more than opportunities. The technology has proven that it can go beyond the frivolous, and that in the right hands it can revolutionize the way we work, learn, and explore. If the market is growing by leaps and bounds despite such serious shortcomings, imagine the demand if vendors were to create plug-and-play components that could be easily configured for the full spectrum of applications. That would truly be the way to reach the mainstream.



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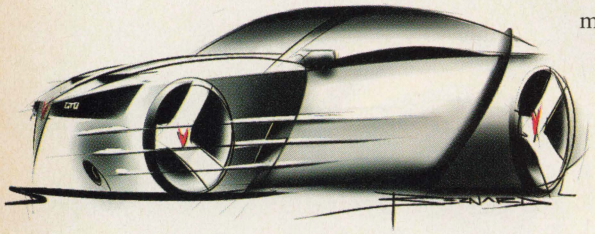

Software No Substitute for Good Design

As a former GM designer, I was interested to read about the Pontiac GTO project mentioned in "Back to the Future" (July 1999, pg. 23). The GTO concept car raises an interesting issue regarding the effectiveness of computer-aided industrial design. All the processes used in developing the car's exterior were extremely efficient, but the outcome was ineffective. While the computer was employed successfully in speeding the development time, enabling designers to go directly from computer model to prototype, the retro-GTO suffered from brutal edges, a lack of subtle surface development, and the absence of a theme, looking nothing like the '60s or '70s GTOs.

This is especially obvious when comparing the GTO to Dodge's Charger R/T concept car, which was also displayed at the Detroit Auto Show. Chrysler's designers understood and captured beautifully the essence of the Dodge Charger from the late '60s.

Although there is legitimate value to what a talented designer can accomplish with the aid of the computer, advanced technology doesn't make up for bad design or ineffective design processes. Potential customers don't buy processes; and they won't be swayed into thinking that a design is good because of the technology used in its creation.

CAD styling tools do have a place in the development process if they are used to speed the creative ideation of new designs. When implemented effectively, they allow a designer to more quickly explore various ideas and to take them further than older methods. This allows decisions to be made earlier about which designs should be developed into full-size clay models, or if the proposal should be abandoned.

But even though a virtual 3D model theoretically allows you to bypass clay-modeling steps and go directly to real prototypes, proper development and evaluation methods won't skip the full-size clay model and the necessary tweaks by talented professionals to fully develop good form and great design. Automotive forms are extremely complex, and it takes a great deal of artistry, talent, and experience to develop them.

At GM, Alias is used more by older, experienced sculptors than by designers. A sculptor who really knows form can save time by working out the forms originating from design input (like scanning a hand-done scale clay model), then cutting a full-size clay model with a mill. This does save time and effort, but interestingly, less experienced modelers can't do it, because they don't know form sufficiently. And obviously the computer program can't do it by itself, either. Even after the most experienced sculptors work out forms in Alias and the full-size clay is milled, they still go back and finesse the model to get the forms right.

Companies hire people who can run programs but don't have the experience or talent to use them creatively. In an effort to get rid of clay and paper, auto companies have invested heavily into technology, only to find that the new tools aren't up to the job. When I was at GM, we sketched cars, made tape drawings, did full-size renderings, and worked with sculptors to develop the models. All the designers had a set of markers and a box of chalk, and we all used the same kind of paper. But some of those designers created stunning artwork, while others just got by in comparison. My point is that in the same way, the computer is just a tool that in the hands of creative talent and perceptive management can be a powerful aid to the development of great products. But when it is relied upon too heavily by less-experienced people, or is managed poorly, the results can be terrible.

Gary D. Smith
Performance Design
Cave Creek, AZ

Artistic Talent Not Required

I'm attending the University of Illinois this fall, and I'm interested in pursuing a career in computer graphics in the film industry. I am fairly good at math, and I like to think I'm a proficient computer user. A possible problem, however, is that I am not as artistically talented as some other people I know. Will this greatly hinder me in my chosen career? If it does, I would like to hear any suggestions your readers might have regarding alternatives in the computer graphics field (preferably ones that still have to do with film).

Doron Galili
Chicago, IL

Editor's Reply:

A suggestion, from an editor at Computer Graphics World, *was to study computer science and learn how to program in C++, and at the same time, study filmmaking so that you will understand the craft. You don't have to be artistically talented yourself—you just need to understand what kinds of tools artists need, and then know how to create those tools. That's one idea. Perhaps our readers will offer additional suggestions.*

Smoke, but No FireWire

I just finished reading the review of SGI's 320 Visual Workstation (July 1999, pg. 67) and had to wonder if your reviewer actually turned the thing on. The reason I bring this up is that at the bottom of the review he says, "Overall, video quality was good, particularly with the FireWire ports." I have a 320 and it does have FireWire ports, but they are inactive. SGI says they won't be active until Microsoft releases its next version of NT, because NT currently does not support the FireWire spec.

John Phelps
San Francisco

Author's Reply:

The FireWire ports on the SGI 320 are indeed inactive. While reviewing the machine, I inadvertently captured through the analog ports and assumed the data was coming through the FireWire ports. SGI will support these ports only when Windows 2000 is released. My apologies for the error.

George Maestri

We Value Your Input

We welcome any insights you may have that would further our readers' understanding of topics discussed in this issue. We may edit your response to conform to our style and space requirements.
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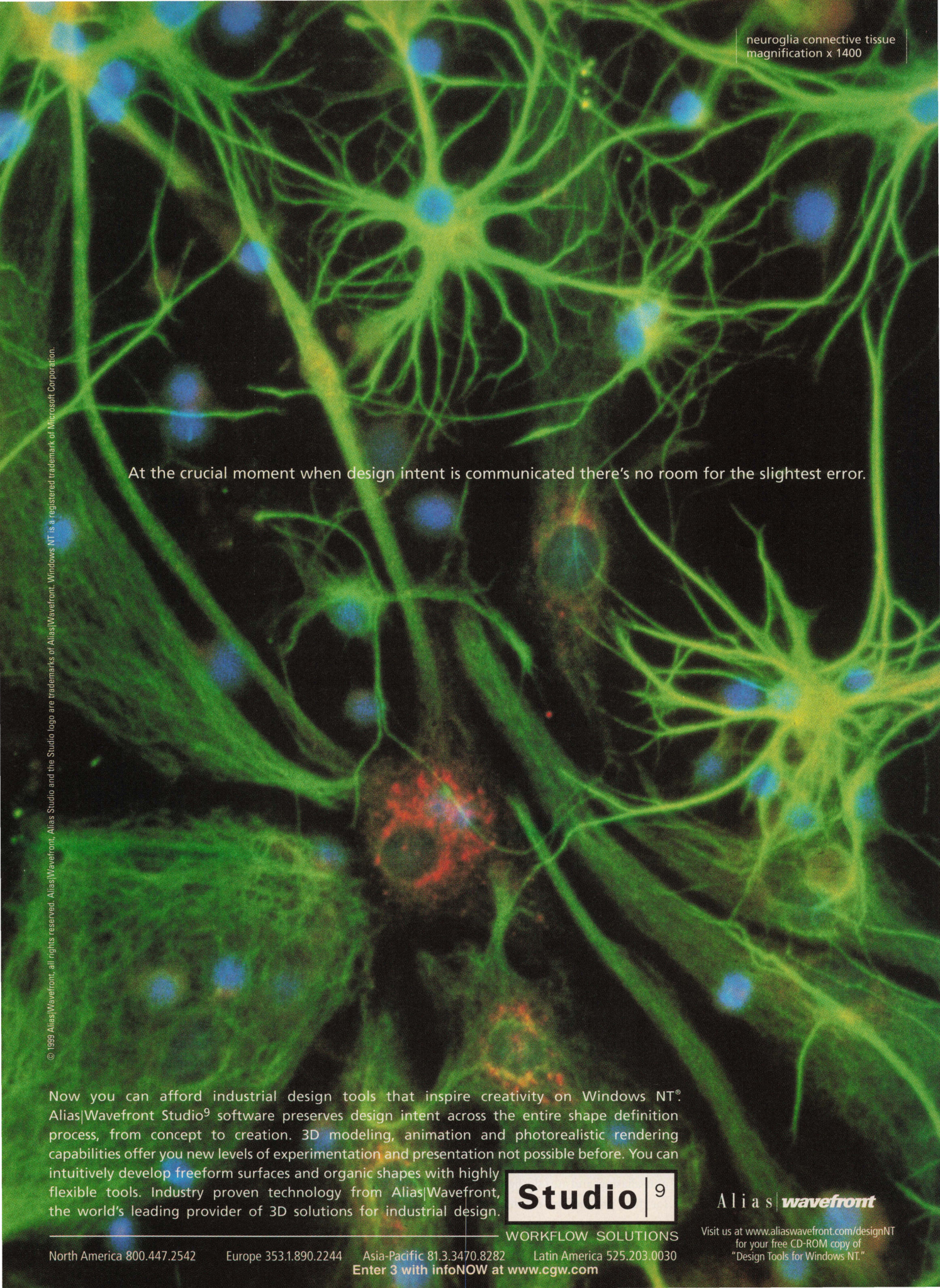
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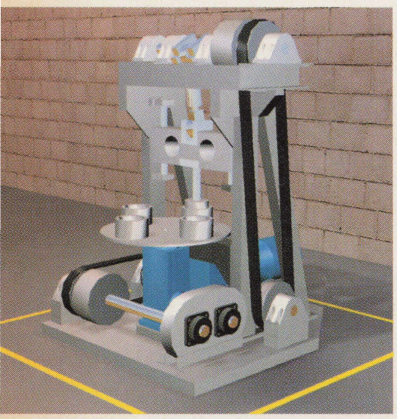
SPOTLIGHT

Autodesk Does Assemblies

The sixth major release in two years of Autodesk's mechanical CAD software, Mechanical Desktop 4, offers a number of significant design and productivity enhancements. The most notable are what Autodesk bills as "assembly-centric tools" for the efficient creation, editing, and management of assemblies. These include in-place reference editing, which lets users edit external parts and write the modifications back to the external file within the assembly context, and a redesigned catalog, which facilitates the unloading and reloading of external components to combine external toolbodies and local parts into a single component. With the latter feature, external files are available for concurrent engineering, and users can drag and drop components from external to local use.



Among the software's productivity enhancements is the integration of AutoCAD's Multiple Document Environment (MDE), through which users can access and edit multiple files in a single session and copy or move model geometry between drawings. Additionally, Mechanical Desktop 4 incorporates the new ACIS modeling kernel from Spatial Technologies, increasing modeling performance.

New design features of Mechanical Desktop 4 include the ability to incorporate splines in the creation of profiles and support for image "quilting," whereby users can stitch together multiple surfaces or solids that can then be parametrically edited and manipulated downstream. Among the software's drawing improvements are advanced hidden-line (AHL) generation, automatic centerline creation, enhanced zoom functionality, parametric dimensioning on parts in all views, diametrical dimensioning on edge views of arcs and circles, and new breakout and radial section views.

These design and productivity enhancements, as well as a streamlined user interface and a number of features contributing to the product's ease of use, will further increase Mechanical Desktop's appeal to mechanical designers, says industry analyst Bruce Jenkins of Daratech (Cambridge, MA). "Mechanical Desktop is already the fastest-selling mechanical solids-modeling software product on the market. This release will no doubt fortify that success."

In addition to the capabilities of the base product, the Mechanical Desktop 4 Power Pack includes a library of 800,000 2D and 3D standard parts, engineering calculations, and the functionality of AutoCAD Mechanical 2000, which provides 2D mechanical design extensions on top of AutoCAD.

Designed for the Windows 95/98/NT platforms, the Mechanical Desktop 4 base software is priced at $4995 in the US. Upgrade pricing is available. (San Rafael, CA; 415-507-5000; www.autodesk.com)

—Diana Phillips Mahoney

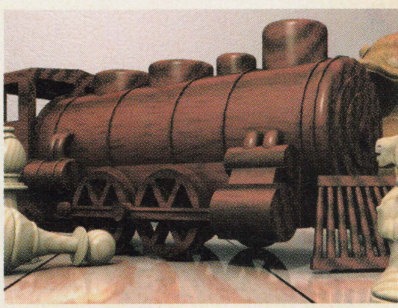
infoNOW 60

Interactive Photorealism from LightWorks

The LightWorks rendering engine, used in 3D applications from companies such as autodessys, Digital Immersion, Gestel, IMSI, SolidWorks Corp., think3, and Unigraphics Solutions, has now entered its fifth release. According to supplier LightWork Design, the new engine is the first such 3D component software to offer interactive photorealism to application developers. The integrated Interactive Image Regeneration (IIR) technology provides users with instant visual feedback on 3D designs.

Other new features are hybrid shadow creation, which combines ray tracing and scan-line rendering for quick and efficient production of ray-traced shadows; perceptual tone mapping; shader parameter ranges; a variety of wood surfaces for better visualization of doors, cabinets, parquet floors, and so forth; analytical anti-aliasing; and area sky lighting for fast production of interior light from windows or doorways. The new engine also includes an anisotropic reflectance shader for woven materials, a leather shader, and a multi-layer paint tool.

At think3 (Santa Clara, CA), creator of the CAD program thinkdesign, the LightWorks engine was used as the basis of the company's rendering module, thinkreal. "We wanted to make the product as simple as possible," says Max Sims, product manager. "We evaluated several systems, and LightWorks offered the cleanest, most elegant interaction for our users. It has a lot of intelligence builit-in, so people can get to the power without having to do a lot of programming."



The Lightworks SDK is available in four different packages: SuperLite, Lite, Classic, and Pro, with the latter product representing the full-featured version. Prices for the kits start at $3300 and run to $40,000, in addition to royalties based on volume. (Sheffield, UK; 44-114-266-8404; www.lightwork.com)

—Jenny Donelan

infoNOW 61

Modeling for Less

Digital Immersion Software Corp. has introduced two 3D packages that emphasize speed and affordability. Both Merlin VR and Merlin 3D are based on the Direct 3D engine, and both programs owe their speediness in great part to code optimization performed at Digital Immersion.

Due out this fall is Merlin 3D, a $595 modeling and animation tool that, according to its developer, handles models as large as 200,000 polygons and textures of up to 2048 by 2048 pixels with little more than a performance hiccup. Merlin 3D comes with hybrid radiosity, ray tracing, Phong shading, and volumetric lighting. Users can create and play back animations in real time, and view fully textured scenes at speeds greater than 15 frames per second. The program also has an extensive texture library, a set of modeling primitives, and a variety of lighting effects. Merlin 3D runs on Windows 95/98 or NT 5.0. It requires a minimum of 32MB of RAM, 100MB of hard-disk space, and a Direct 3D-compliant video card.

Already shipping is Merlin VR, Digital Immersion's interactive-content tool that is aimed primarily at Web developers and entry-level digital content creators (although a CAD-optimized version is now available from the Web site). With Merlin VR, users create Internet-ready objects, animations, and VRML worlds that can be previewed in real time without rendering, then output to .avi format. The program runs on Windows 95/98 and requires a minimum of 32MB of RAM, 200MB of hard-disk space, and a graphics accelerator (Direct 3D preferred). Merlin VR costs $129, or $99 as a try-before-you-buy Web download.
(Toronto; 877-272-0804; www.digital-immersion.com)

—JD

Crossing the Rubicon

The solid-modeling program that Autodesk (San Rafael, CA) has been preparing for release under the code name of Rubicon now has a name: Autodesk Inventor. According to Autodesk, Inventor is based on a new, proprietary adaptive architecture that will allow designers to lay out and connect components by specifying shapes and positions rather than parameters and equations.

A recent report from market analyst Daratech (Cambridge, MA) predicts that the new modeler will take aim at high-end products such as Dassault Systemes' (Paris) Catia, Parametric Technology Corp.'s (Waltham, MA) Pro/Engineer, SDRC's (Milford, OH) I-DEAS, and Unigraphics Solutions (St. Louis).

A price and ship date for Autodesk Inventor had not been announced at press time.

New Internet Service for Manufacturers

Engineering Animation Inc. (Ames, IA) and Hewlett-Packard Co. (Palo Alto, CA) have jointly announced a so-called e-services portal for the manufacturing community. E-Vis.com will provide an Internet venue for collaboration among enterprises and suppliers, with available services including integration between companies and teams, product data management over secure Web servers, conferencing, and a training center and marketplace. Contact e-vis.com for information regarding monthly subscription fees. The site is in operation at www.e-vis.com.

Digital Sculpture Competition

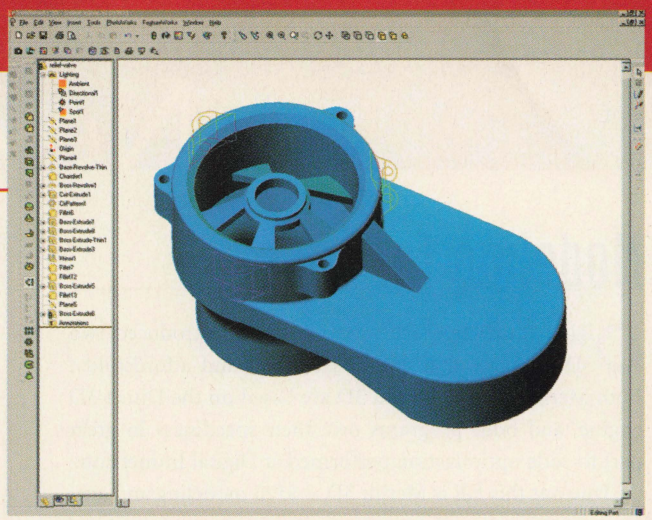
InterSculpt '99 has announced what it claims is the first digital sculpture competition, open to anyone who can create a virtual sculpture that can be output with a rapid-prototyping device. Regulations and registration information can be obtained at www.toile-metisse.org/intersculpt/dsc.htm. The competition closes on September 15, 1999. Winners will be announced on October 8.

In Brief

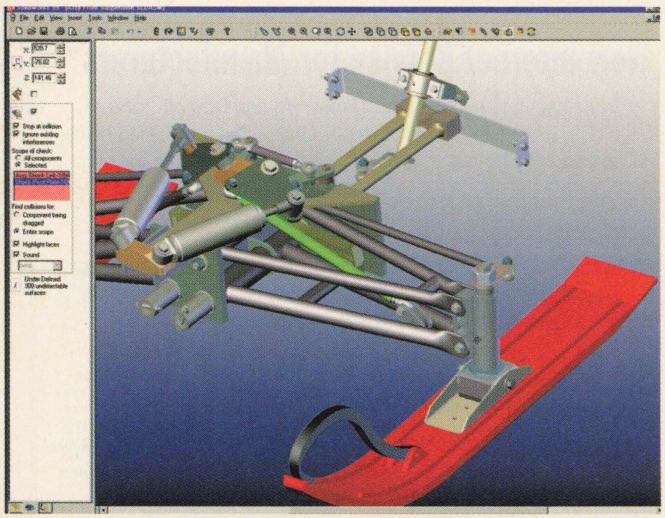
IBM (Armonk, NY) and **Sequent Computer Systems** (Beaverton, OR) have entered a merger agreement under which IBM will market Sequent's high-end servers, used for datawarehousing and business intelligence applications.... Graphics and video accelerator provider **S3** (Santa Clara, CA) will acquire **Diamond Multimedia Systems** (San Jose, CA), also a maker of graphics and video accelerators, as well as Internet audio and home networking products.... **InterSense** (Burlington, MA) and **Sony Broadcast & Professional Europe** will be jointly producing the Sony Glasstron LDI series of personal display systems that will come bundled with InterSense's InterTrax inertial tracking system.... Multiple-monitor card maker **Appian Graphics** (Redmond, WA has been acquired by a private investment consortium whose capital will be used to further product development.

—Jenny Donelan, Managing Editor

SolidWorks Enhancements



SolidWorks 99, the latest release of the Windows-based mechanical design software from SolidWorks Corp., features enhancements to parts modeling, detailing, and assembly design, as well as expanded sheetmetal design and data exchange capabilities. Chief among the modeling improvements are dynamic editing, in which users can reshape a surface or feature in real time, and a 3D sketcher for creating pipes, tubes, wires, and free-form shapes. New detailing tools include support for setting layers, colors, and line fonts, automically generated, customizable, bills of materials, and a new graphical editing interface, with the option of an AutoCAD command line emulator that will help engineers more familiar with 2D CAD make the transition to 3D. Among assembly design improvements are real-time collision detection, assembly structure editing, and enhanced SmartMates, with snap-to-fit capability added to the feature's automatic capture of assembly-mating relationships.



SolidWorks 99's sheetmetal improvements include new rip-edge capabilities that allow users to convert boxes and other 3D shapes into sheetmetal parts, and the ability to unroll conical parts. Among the new data exchange features are expanded support for DXF and DWG imported files, and the ability to run surface healing on imported files (identifying problem areas and removing or replacing them).

A powerful new option for designers is SolidWorks Piping, a pipe creation and editing package that includes a fittings library with more than 1700 parts. An automatic fitting selection offers engineers access to only those fittings that will work in a given connection, thus minimizing design errors.

SolidWorks 99 requires Microsoft Windows 95/98/NT, a Pentium-based computer, and a minimum of 64MB of RAM. The price for the package is $3995. SolidWorks Piping costs $495.

(Concord, MA; 800-693-9000; www.solidworks.com)

—JD

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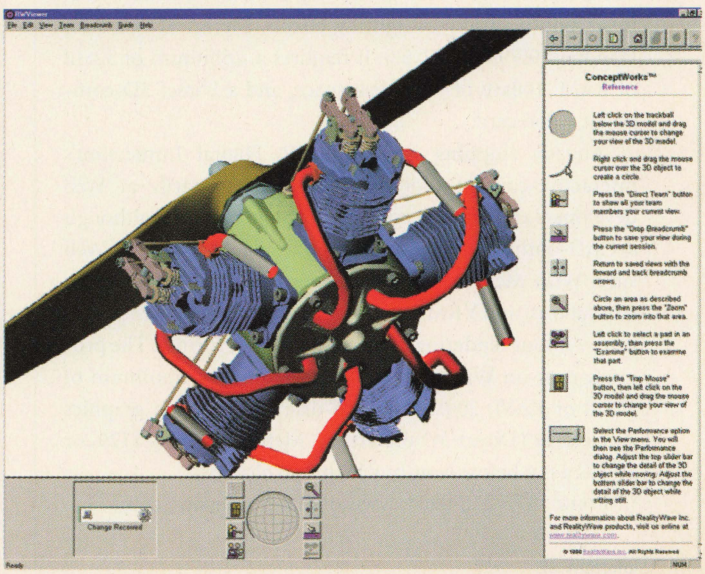
Full Stream Ahead



Amid the recent tidal wave of collaborative CAD tools, vendors are taking different tacks in order to stand out. In the "simpler is better" category is ConceptWorks, a SolidWorks add-in from newcomer RealityWave. Proprietary streaming technology allows non-SolidWorks users to view and manipulate not only parts, but also complex assemblies in real-time over the Internet, even over dial-up connections. ConceptWorks collaborators address a simple interface that allows them to view an image, change its orientation, and highlight sections of the design.

The add-in costs $1995 for the first seat at a site, with reduced prices for additional seats. RealityWave plans to use its patented streaming technology in future products that will work with other CAD programs.

(Cambridge, MA; 617-492-0900; www.realitywave.com)

—JD

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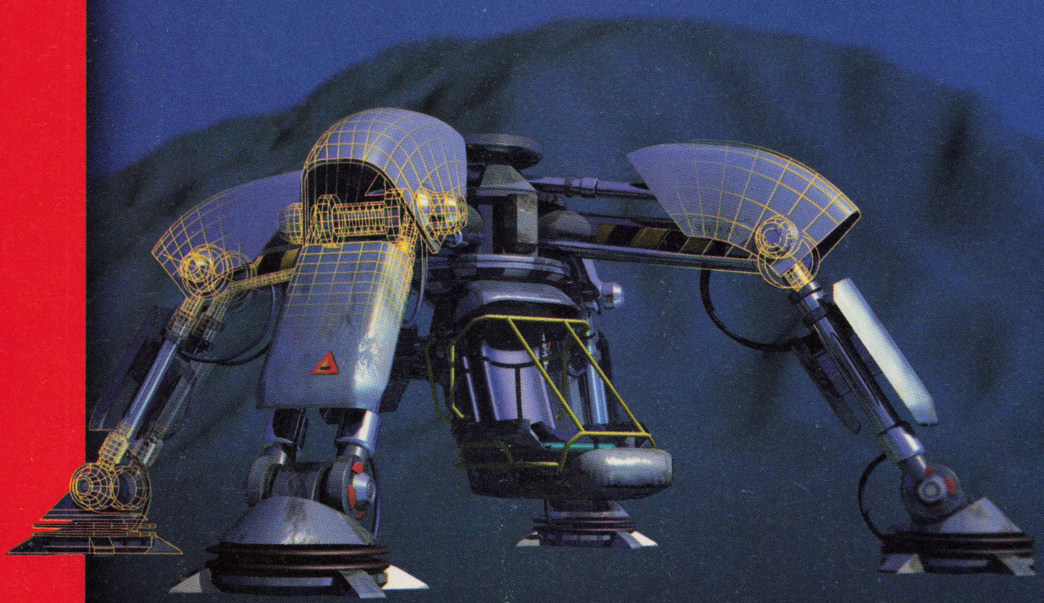

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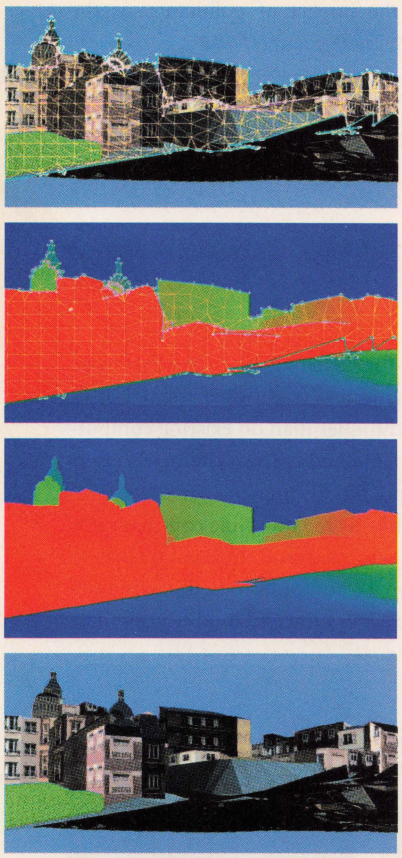
Visualization with Urban Appeal

Researchers build cities using 3D geometry and "imposters"

BY DIANA PHILLIPS MAHONEY

The potential value of computer visualization in urban design has long been appreciated. The ability to visualize and interactively manipulate the detailed, complex data that defines any urban scene promises significant rewards for such applications as site planning and pre-construction visual-impact studies, city growth planning, the development of navigational aids, civil and military simulations, education, and virtual tourism, among others. Unfortunately, technical obstacles have kept the technology's potential from being fully realized, despite the fact that, in recent years, a number of commercial visualization tools have attempted to break into the urban-design market. Typically, these tools are ill-equipped to handle the visual complexity that urban models must contain in order to be useful to the broad range of urban design and planning applications.



Creating image-based "imposters" involves covering each layer of images in the urban scene with a 2D mesh (top), which, via a depth map, is transformed to 3D. The final step is to texture map each of the polygons of the mesh.

In an attempt to exploit the technology's potential advantages in this arena, researchers in the Computer Graphics Group at the Massachusetts Institute of Technology (MIT) in collaboration with the iMAGIS group (a French research consortium sponsored by CNRS, INRIA, and Grenoble Universities) are working to simplify city models for interactive visualization. To this end, they have developed a system for the high-performance visualization of urban scenes that bypasses some of the memory and processing issues weighing down most commercial visualization systems.

At the core of the system is a hybrid modeling approach that comprises both 3D geometric models and image-based representations called "imposters." The geometric models are used to depict objects close to the user, and the imposters are used for background items—"things you can see but that you can't actually reach out and touch," says MIT researcher Julie Dorsey. As the user moves through the scene, objects move in and out of the near and distant fields based on the user's perspective at each step. "At any given point, we're trying to come up with a combination of images and geometry that will allow us to have a very accurate view of the scene, and one that will also allow us to navigate interactively through it without any loss of quality," says Dorsey.

Both 3D geometric models and image-based representations ("imposters") depict a Paris scene. Depending on the user's perspective, objects move back and forth between these two types of representations to minimize the processing drain of the real-time visualization.

The first step in achieving this goal is the definition of local and distant fields of data. To do this, the system first computes a set of objects that may be seen from a point on the edge of the scene, then implements a sampling algorithm to take several pictures along the edge in different directions and to retrieve visible objects from each picture. The distance from the center of each of these objects to the edge determines whether it's treated as local or distant.

In addition to "swapping" items based on their local or distant distinction as the user's perspective shifts, the system compensates for the resulting parallax effects—the appearance that objects

in the background move in relation to each other as the user's view of them changes.

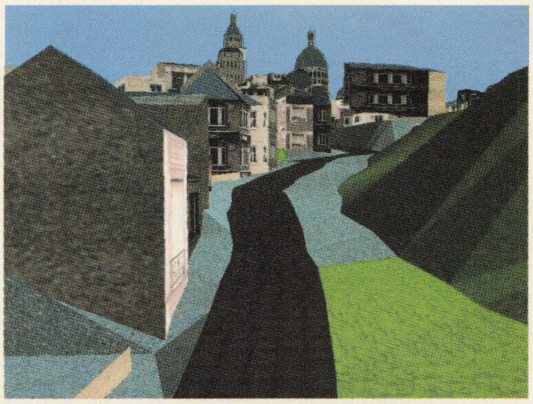
The next step is the creation of image-based imposters. This involves covering each layer of pictures with a 2D mesh. Using a depth map, the planar map is transformed to 3D. Finally, texture maps are applied to each of the polygons of the mesh.

The imposter approach differs fundamentally from the polygonal simplification strategies employed by traditional visualization systems, such as object culling and level-of-detail switching, because the imposter isn't a flat image. Rather, it's a 3D mesh constructed using the geometry of the actual model. The resulting 3D representation enhances the user's perception of realism, says Dorsey. "We can view these imposters from multiple points of view and they're still valid, so we can get the occlusion and parallax that you would get as you're moving around in a city."

While this visualization system could be useful for any application involving navigation through and interaction with huge geometric datasets, the researchers are focusing initially on urban environments because such environments are both visually complex and highly structured in their grid-like network of streets and landmarks. "We leverage off of this structure in building our representations," says Dorsey. "If you just assume you've got a bunch of random geometry, it's a much harder problem, because you don't know what's important at any given time. You just try to visualize everything at the same level of detail." Such an approach is particularly ineffective for urban scenes, which not only span large areas, but also contain objects with rich visual detail at many different scales.

With this in mind, the biggest challenge the researchers face is the creation of an architecture capable of handling the various 3D representations with no apparent image degradation. "Cities are difficult because of their geometric detail. From a certain view, you can see all the way across the city to a park. There's just so much data in terms of the textures and the polygons. Our goal is to organize and access the data in the most efficient way at any given time."

The researchers are currently developing models of Boston and Paris. "They're not as realistic as real scenes yet. We'd like to move toward having more complex geometry with better textures and better lighting conditions," says Dorsey. To this end, the researchers are are working to improve the imposters and to add realistic lighting effects. Eventually they hope to be able to simulate such phenomena as plant growth, the impact of pollutants, or the effect of climate changes.



A city view is full of detailed objects near and far. Image-based representations of the far objects let researchers display more detail in the close objects.

Diana Phillips Mahoney is chief technology editor of Computer Graphics World.

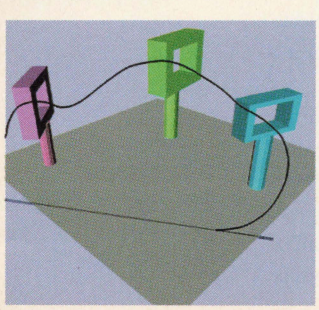
Throwing Artists a Curve

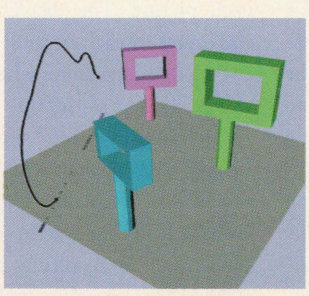
A novel interface lets artists use familiar skills to draw 3D curves

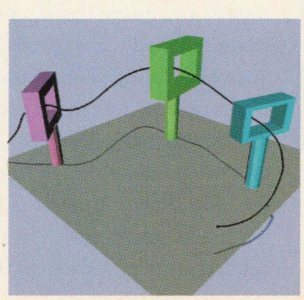
There's no question that the availability of computer-based 3D design tools has opened up tremendous creative opportunities for artists. There's also no question that in order to take advantage of those opportunities, artists have had to acquire skills far above and beyond their classic design training. Even the most accomplished traditional artists have to start from ground zero to learn how to translate their technical skills to the digital realm.

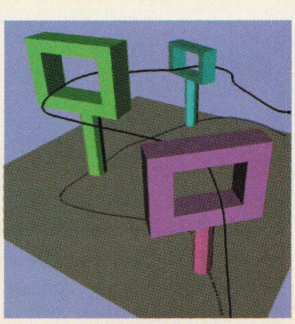
In an effort to change this scenario—basically, to suit 3D design software to the artist rather than trying to suit the artist to the design software—researchers in Brown University's Computer Graphics Group have developed an interface for sketching 3D curves that more closely mimics traditional pencil-and-paper techniques than do existing computer-design methods. The system lets users create and modify non-planar 3D curves without having to edit spline control points or deal with surface intersections—two "traditional" computer-based techniques for curve generation and modification. The software is one of a

The curve-sketching system developed by researchers at Brown University relies on familiar drawing techniques, so artists can easily sketch curves that can be used to define motion paths through a virtual scene, or camera paths for an animation.









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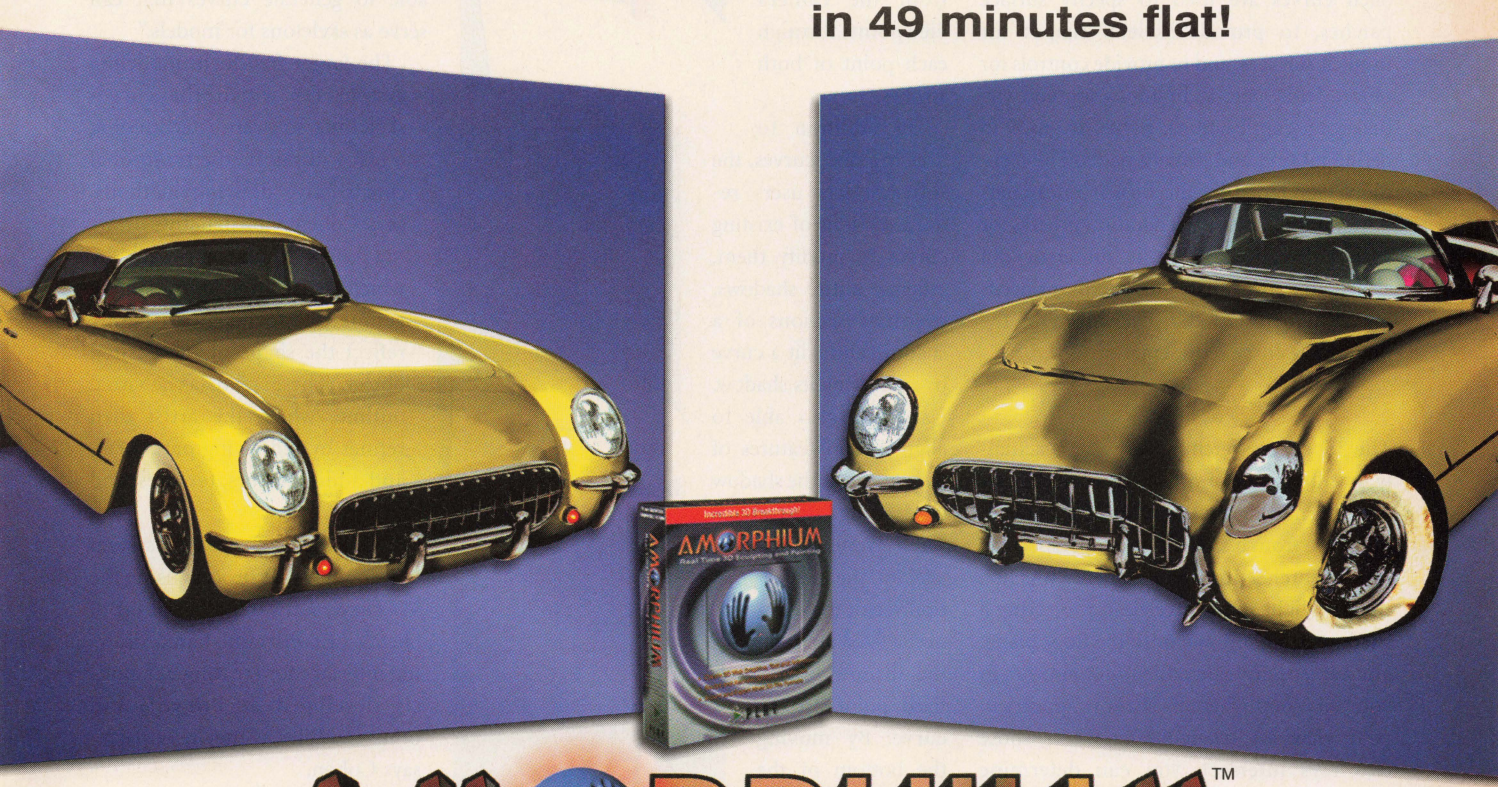

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handful of tools researchers in the group are developing for what eventually will be a broad-based freeform modeling system.

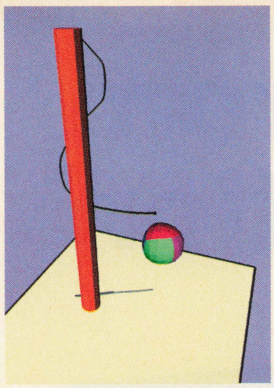
The ability to generate 3D curves is critical to the success of any modeling system. Such curves are used to specify surface patches, to provide skeletal shapes for implicit surfaces, and to provide controls for object deformations. In animation and virtual-reality applications, curves are used to define motion and camera paths. The technique developed by the Brown researchers streamlines the curve-generation process for such applications. With it, an artist can sketch an approximate curve without needing to understand the mechanism of the underlying curve representation.

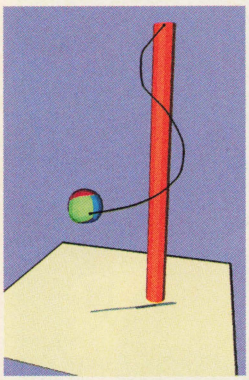
Curves Ahead

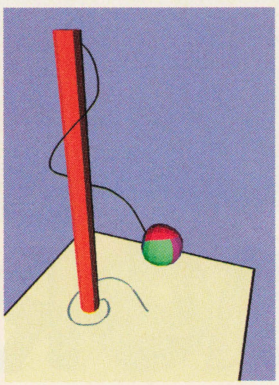
The 3D curve-sketching software is actually an outgrowth of a technique that exists for determining the location of a point in 3D space from a single camera perspective, says researcher Jonathan Cohen. "Imagine there's a light source overhead projecting a shadow straight down onto the floor plane. You can specify where the point appears in your view and where its shadow appears in your view. By triangulating where those two rays intersect, you can determine exactly where the point is."

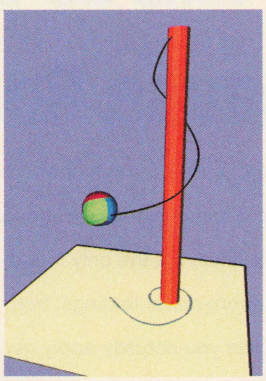
The researchers extended this notion for curves, whereby the user first draws the curve, then draws a second curve to represent the shadow, approximating its alignment to the initial curve with the help of adjustable vertical guidelines at both ends of the curve. Built into the software are constraints defining the validity of a shadow for a given curve. If the hand-drawn shadow doesn't meet the requirements for being a valid shadow for the curve, the system won't accept it. However, says Cohen, "since it's a hand-drawn shadow, it's never going to be exactly valid. So the system recognizes shadows that are 'almost' valid." A shadow-matching algorithm "corrects" the shadow approximation and registers it to the curve.

Once the curve and its shadow are defined, filtering and smoothing operations transform both "strokes" into smooth polylines. The system identifies and matches critical points of the curve and shadow, then infers the 3D shape of the curve by calculating the intersection of all of the rays extending from the camera viewpoint through each point of both strokes.









To define the spiraling curve of a tetherball rope, a user sketches the rope. The 3D curve-drawing system projects a default curve onto a base plane to represent the curve's shadow. The default doesn't give the desired shape, so the user redraws the shadow and the system automatically matches it to the curve.

In addition to drawing new curves, the software lets users redraw sections of existing curves to modify them, redefine entire shadows, overdraw sections of a shadow, and edit a curve by modifying its shadow. Users are also able to align certain features of the curve and the shadow by drawing "struts." These are lines parallel to the projection vector that connect a fixed point on the shadow with a fixed point on the curve. By moving the bottom of the strut up and down, the user can adjust the shadow, while leaving the appearance of the curve unchanged.

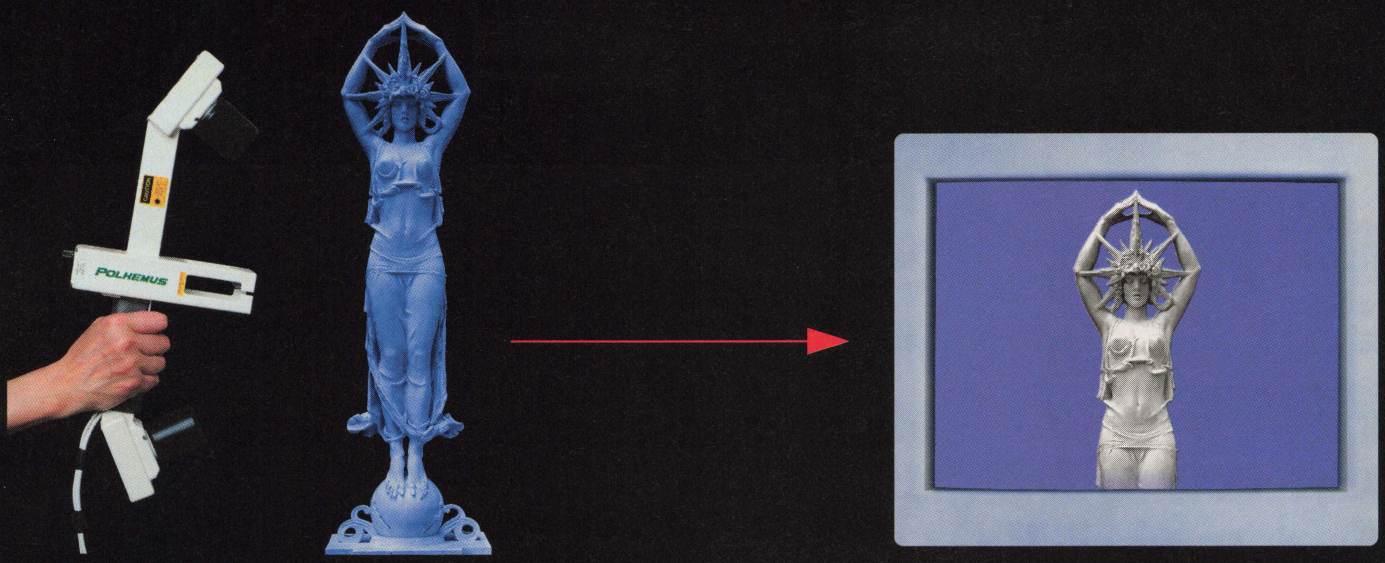
One of the early applications Cohen sees for the curve technology is navigation through virtual worlds. "Basically, you can sketch a curve in a 3D scene, then the camera flies along that path. Someone who's practiced at the technique can create paths that thread over, around, and through all kinds of things, and they can do it in about five seconds." Additionally, the software could provide a framework for a modeling system. "For example, if you have four curves, you can make a magic carpet-like surface from a single-camera perspective. Eventually, we hope users will be able to generate curves that can serve as skeletons for models."

The larger free-form modeling system for which the curve-sketching software is a building block will mimic the traditional constructive drawing methods, says Cohen. Constructive drawing refers to the approach by which artists first draw simple geometric forms to roughly reflect the shape of the desired object. These serve as a visual outline, which the artist then refines by redrawing parts of it, and adding colors, textures, and so forth.

"Our idea is to create a system that models that process using the 3D curve software, a variation of Sketch [a constraint-based drawing interface for creating 3D models developed at Brown], and other modules as they're written," says Cohen.

While the models created with such tools can certainly be achieved using traditional design software, the creative process behind the models is what's unique, says Cohen. "We're trying to tip the balance toward the artist community. Graphics tools grew out of CAD and manufacturing, and they still really reflect that. Even though some of the high-end tools have some intuitive controls for editing curves, they don't hide the fact that what you're dealing with is a very complex mathematical object. We're presenting an alternative to that type of interface—one that the skilled artist can pick up and run with."

Diana Phillips Mahoney is chief technology editor of Computer Graphics World.



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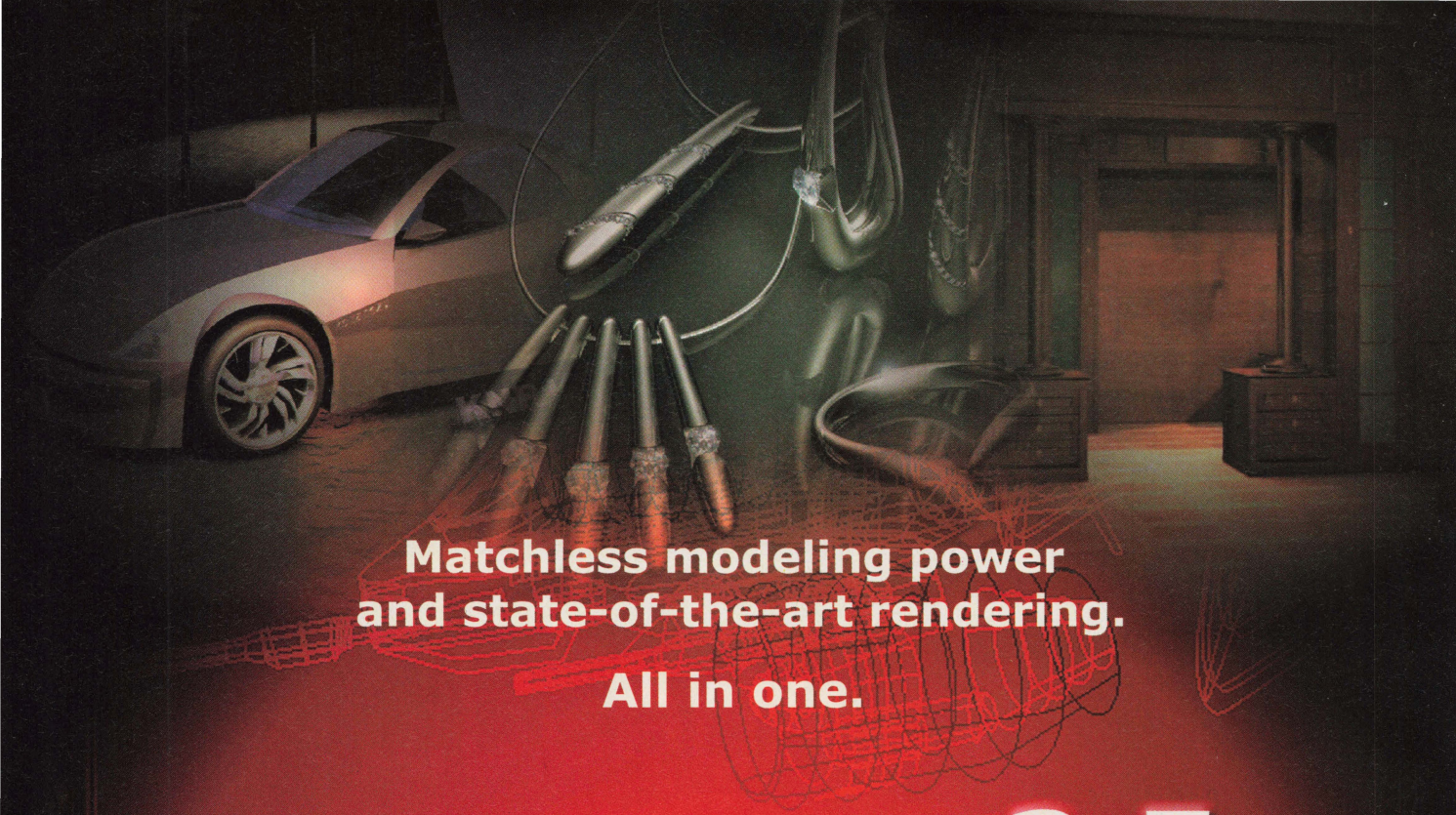

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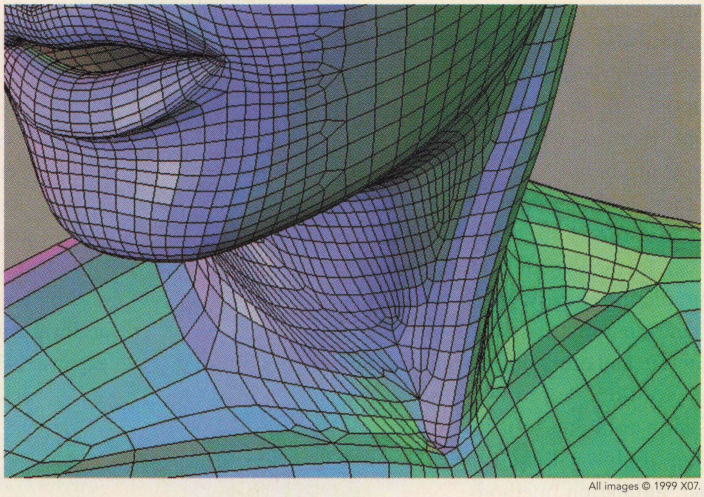
The Evolution of Digital Characters

Ten years ago, senior executives at Disney Feature Animation said, "We will never have a digital character star in an animated film." Now Disney is creating the movie *Dinosaurs* with an entirely digital cast. Several films have already featured virtual protagonists, both in full animation à la *A Bug's Life* and *Antz*, and composited into live action as in *Star Wars Episode I: The Phantom Menace* and *The Mummy*. What do these increasingly sophisticated characters mean to the future of the entertainment business? More important: What will they mean to each of us in our daily lives?



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Now is a good time to look both ways as we cross into this exciting future. For those of us interested in 3D character animation, the patterns are becoming clearer, and a series of development stages past, present, and future is emerging. The first, second, and third stages feature the evolution of animation as we know it today. The last two stages will play out through the early-to-mid 21st century, and will advance animation in some entirely new directions. In stage four, we'll see the beginnings of character autonomy, and in stage five, we'll encounter digital characters with emotional and cognitive lives of their own.

Our newfound virtual friends will handle many of the details of our daily lives

BY MATT ELSON

STAGE 1 • KEYFRAME ANIMATION: This "apprentice" phase of 3D character animation, which began in the late 1970s and continues today, is patterned on the workflow of early 20th century cell animation. Keyframe animation refers to the process of positioning a character every few frames, then letting the computer interpolate the in-between frames. In traditional cel animation, keyframes are drawn by the master animator, with an "in-betweener" filling in the motion. With digital animation the process is the same, but the computer fulfills the role of in-betweener.

A primary innovation of this phase is programmable expressions, in which technical directors define interactive relationships in the 3D environment. An example is the flexing of associated skin or muscles when a joint is bent. Other noteworthy developments of the keyframe animation era include restructured hierarchical objects, 3D paint, and socking and skinning.

These elements have combined to allow the development of an aesthetically and economically viable method of producing film at roughly $1 million per finished minute in the early '90s, down to about $600,000 per minute at the present time.

Despite the obvious progress that has been made, Stage 1 presents us with several difficulties. Keyframe animation is cumbersome and requires large crews and complex infrastructures with a high ratio of technical-to-creative talent. Control of the characters is generally achieved at the expense of production efficiency.

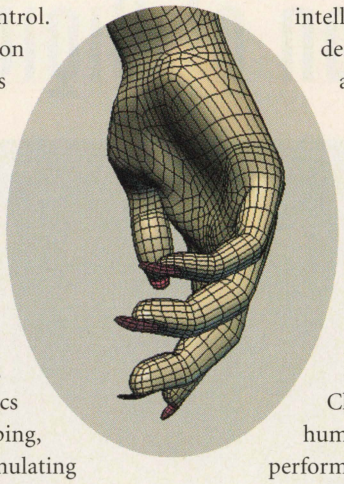
STAGE 2 • LAYERED ANIMATION AND SINGLE SKINS: The crucial goal of Stage 2, (which we haven't reached), is the creation of a workflow that allows animators, programmers, developers, artists, and technical directors to easily address their respective areas of production, which are, at the same time, all integrated with each other. Most major software vendors are trying to retrofit to such a digital workflow now.

Stage 2 developers are also reorganizing the production system around improved APIs, which will allow third-party developers to write object-oriented system extensions and plug-ins, clearly define time and space relationships, and utilize layerable animation allowing different motion types to be combined on the same character.

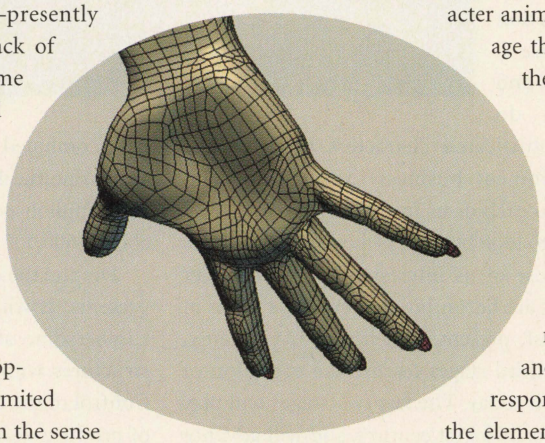
Stage 2 is a rearchitecting, or a required maintenance layer, depending on your point of view, that will radically improve the animation environments' infrastructure and allow software tools that have previously been tenuous extensions to gain a solid foundation in the source code.

STAGE 3 • SCRIPTED MEMORY AND BEHAVIOR: In this stage, 3D character animation will be fully developed for film in the foreground, mid-ground, and background,

and will bring with it powerful crowd control. Since these capabilities can now be built on the workflow developed in Stage 2, tools that had existed as arcane and temperamental system extensions—or separate operations that were somehow integrated—can now become seamless parts of the production flow, thus allowing greater scene richness with lower cost and less aggravation.



Among these tools are particle systems for creating hair, fur, cloth, clouds, smoke, grass, and so forth; dynamics and physics tools for simulating gravity, motion damping, and wind; and anatomical systems for simulating muscle, bone, fat, and other underlying structures of the body. Motion capture—presently reviled by animators due to a lack of good editing tools—will become just another animation method rather than a last-resort nightmare. Skeletons will become a single structure that can instantly mirror a pose (so symmetric actions become simple) and retain position and motion memories.



Stage 3 will also see the development of characters able to retain limited amounts of knowledge—at least in the sense of "performance blocks" that will be most useful in games and on the Web. Basic character-defining actions can be kept internally and played out in time, eliminating the need to constantly reanimate actions like walks and runs. Those building blocks can in turn be used in behavioral crowd simulation for flocks, schools, and traffic, as well as crowds of people.

By and large, for development of linear narratives in film and television, where a story and its performances are crafted in studios and spontaneous performance is not required, Stages 1 through 3 will be all that are required for character animation. But that's not where 3D characters will stop developing.

STAGE 4 • CHARCTER AUTONOMY: Here true character independence will begin, with body physics that allow the character to move about an environment with weight and mass and improvisational behaviors that will give the appearance—though not yet the fact—of intelligence. Animators will still be in great demand to craft all of a character's behaviors, actions, and responses. This stage will be great for games and for active Web sites.

STAGE 5 • PERSONALITY: Characters will then develop emotional and cognitive interior lives. They will begin to "think" and interact with their environment, each other, and the animator and end-user, employing knowledge structures for their basic decision-making. Characters will understand and respond to human speech, so they will be able to translate, perform menial tasks, and sift and sort the digital expanses. With the completion of Stage 5, 3D character animation will be poised for a golden age that will be a cultural hallmark of the first half of the next century.

These stages outline an ideal world: There is no company or facility systematically proceeding from one neat and tidy level to the next, because software companies are busy responding to market demands and production companies are busy responding to their clients' visions. All the elements I've mentioned are indeed in development in various places, though most are in limited use, lacking systematic integration and a compelling economic reason to be pulled together.

But this will happen—sooner or later—depending on circumstances. And when it does, for good or ill, our newfound digital friends will follow us through the Web, entertaining us, yes, but also taking care of many of the details of our lives. More than agents, they will be something I don't think any of us can exactly define or conceive of yet.

The idea of digital characters with minds of their own is frightening to some people. For my part, however, I've always enjoyed these scary technological what-if scenarios, partly because in the long run they turn out to be much different—and usually far more mundane—than we had feared.

Computer graphics pioneer Matt Elson is a principal of X07 (www.xo7.com). He can be reached at melson@xo7.com.

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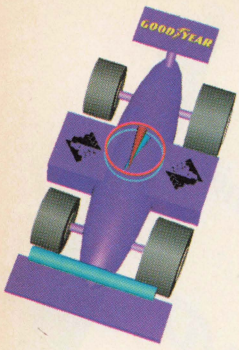


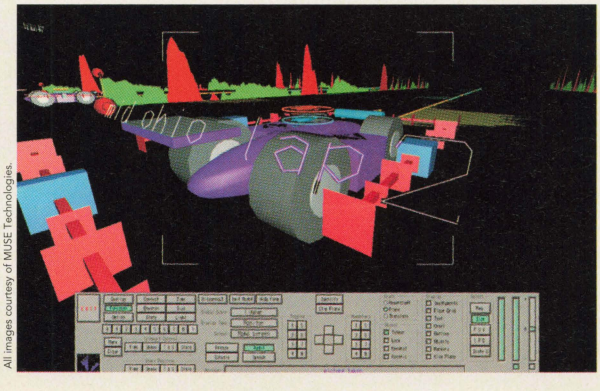
going the

GOODYEAR ADVANCES TIRE R&D WITH HIGH-PERFORMANCE DATA VISUALIZATION

BY KAREN MOLTENBREY

Auto racing has become an increasingly popular sport throughout the country, drawing capacity crowds for most events. But what's a leisure activity for many enthusiasts is an area of important research and development for the engineers at the Racing Division of The Goodyear Tire & Rubber Co. As race cars heat up the track, these engineers and race-car teams collect a multitude of vehicle data, which is later translated into a 4D visualization for real-time analysis of a car's performance and the effects it has on the car's tires—making the day at the track not just another day at the races.

Using a multisensory interface from MUSE Technologies (Albuquerque, NM) that gathers and displays visual, tactical, and audio data, Goodyear race-tire engineers at the company's Akron, Ohio, Technical Center are able to simultaneously view in 4D (3D images along with a time element) graphical format up to 20 types of data describing the state of the car, such as its acceleration, collected from test runs at actual race tracks. The group experiences a lap-by-lap replay of the data, with information about the car's state mapped onto the tires, dials, and vehicle's body, providing a real-time visual representation of performance variables and their effects on the car and tires. By easily visualizing so much data, the engineers have been able to expand their analysis capability, which will lead to improved performance of tires and vehicles in an array of race conditions—and, ultimately, an improved tire design for the consumer market.



All images courtesy of MUSE Technologies.

Using 4D visualization and a multisensory interface from MUSE Technologies, engineers at Goodyear can comprehend some 20 variables of race-car data to evaluate tire performance. This screenshot shows in-line (forward) and lateral (side-to-side) acceleration, load transfer, and other data. That information is also detailed in a popup window for further review.

extra mile

"This application allows us to better comprehend the vast amount of data that is being measured as the car is traversing the track by visualizing what is occurring in 4D. We can more fully understand how the car is behaving and how the measured parameters relate to one another," says Randy Brayer, team leader at Goodyear's Racing Division. "As a result, we can compare the performance of one type of tire versus another, so we can improve the tire design."

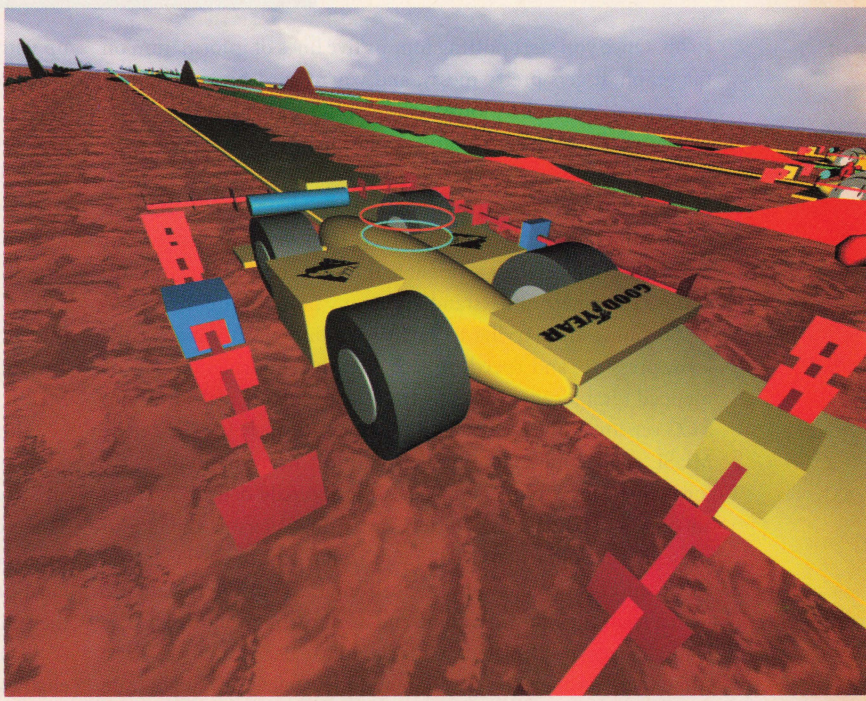
Need for Speed

In these high-speed races, in which cars can reach speeds higher than 200 miles per hour, the winner often differs from the rest of the pack by a few tenths of a second. In this world, dominated by the need for speed, Goodyear is trying to outrun its competition by developing a better-performing race tire that will provide a winning edge on the track and, down the road, on the highways.

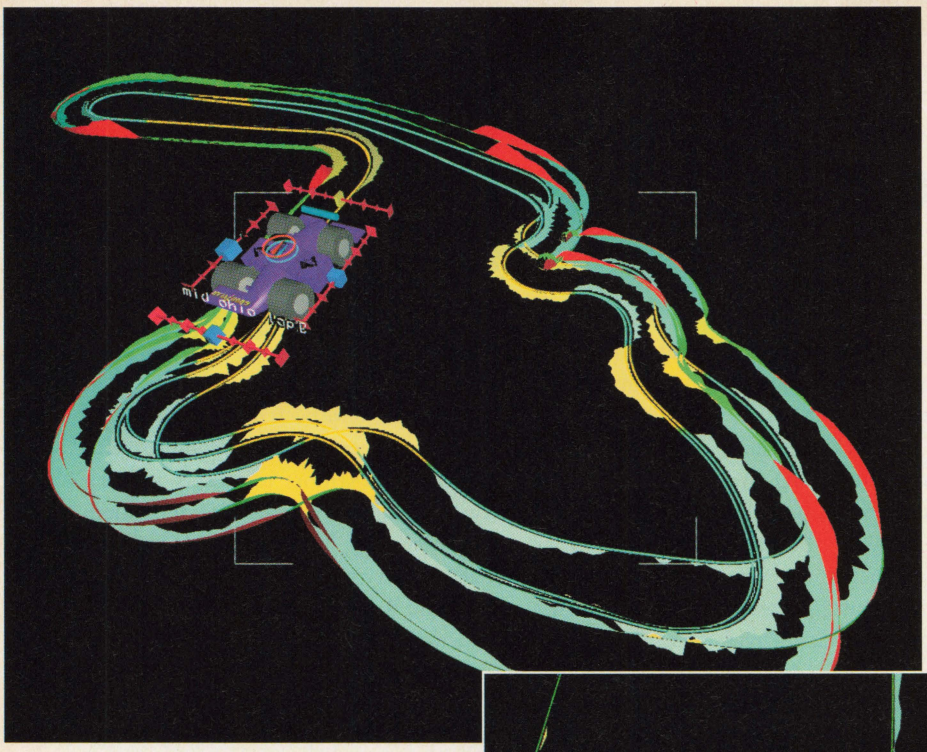
For the past decade, race teams have been routinely gathering a wide range of data (from engine performance to complex aerodynamics) through car-mounted sensors as drivers perform practice laps on race tracks around the world. This information, produced by an application from Pi Research, Inc. (Indianapolis), is collected about every tenth of a second. The data from the Championship Auto Racing Teams (CART) and Indy Racing League (IRL) is then shared with the Goodyear engineers. "We work with teams in the open-wheeled series in that we provide them with test tires, and they evaluate them and give us feedback as well as the [Pi Research] data for analysis," Brayer says. "We look at this data in conjunction with the drivers' comments and lap times, which is ultimately the real test of a good set of tires. Then we go and develop better tires."

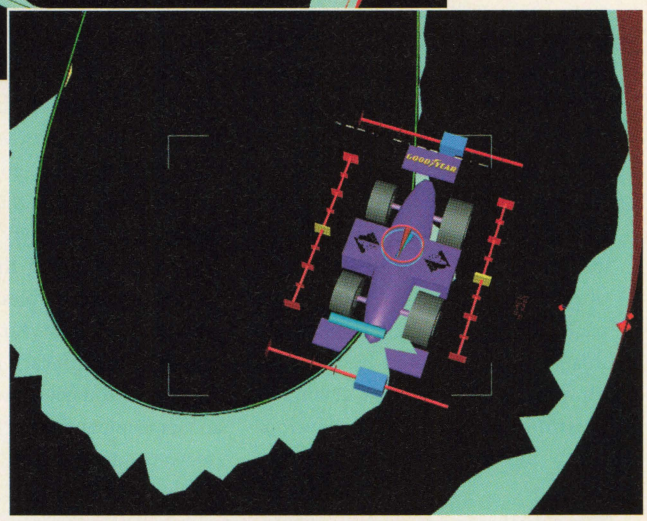
Brayer notes that the tests, like the actual races themselves, are conducted on a variety of track layouts, each presenting specific challenges, enabling the engineers at Goodyear to factor in a wide range of variables about the vehicle's performance.

Until early this year, Goodyear has been charting the Pi data on 2D plots, with each piece of data representing a single line on the chart. "You get a line showing this much lateral (side-to-side) acceleration, and other lines showing a certain amount of in-line (forward) acceleration, air velocity, steering angle, throttle, and



This virtual race car carries more than 15 dimensions of car performance. Its tires swell and shrink to represent pressure changes; the blue and yellow boxes mounted on the red bars along each side grow and shift to alert engineers to load transfers; the dials above the car indicate steering angle and oversteering. The track itself "graphs" lateral acceleration (as dark patches) and a trackside plot shows in-line acceleration and deceleration as green and red vertical peaks, respectively.





Collecting data for three laps on the same curved track (above) is helpful in validating each data set and in choosing useful lap pairings for comparative analysis. As the car approaches a curve (right), the blue data plot beneath indicates an increase in lateral acceleration, and the outside wheels swell to indicate increased pressure.

so on. Once you start putting four or five lines of information on the graph, it gets pretty messy, and you're hard-pressed to fully understand what the plot is telling you," explains Brayer. "The power of the MUSE [Multi-dimensional User-oriented Synthetic Environment] application is in showing upwards of 15 to 20 lines of information, in a graphical way that you can comprehend, while the car traverses the track. It allows us to visualize far more information than is possible through conventional means, and it's extremely understandable at any point in time."

So rather than trying to interpret a line plot to analyze the load, pressure, and speed of each tire, that information can be mapped (graphically and using track-side plots) in real-time onto a CG version of the race car as it traverses the track. In essence, the MUSE application takes numbers and text from the Pi data and turns them into colors and shapes for anomaly detection, trend analysis, and pattern recognition, says Craig Peterson, director of strategic development at MUSE. For instance, the vehicle's lateral acceleration is depicted on the horizontal axis of the track path, with a right turn shown in blue and a left turn in yellow. The tire load changes are depicted as increasing or decreasing tire sizes, while the steering wheel position and the vehicle yaw angle (rate of direction change) appear as blue and red dials, respectively, over the center of the vehicle image.

Furthermore, the previous presentation method only showed lines above and below one another, requiring the engineers to make assumptions in the data, such as when a car is entering and exiting a turn. With the MUSE application, the engineers can actually see the performance of the vehicle at the entrance into Turn 2, for instance, and see at exactly which point the driver is decelerating.

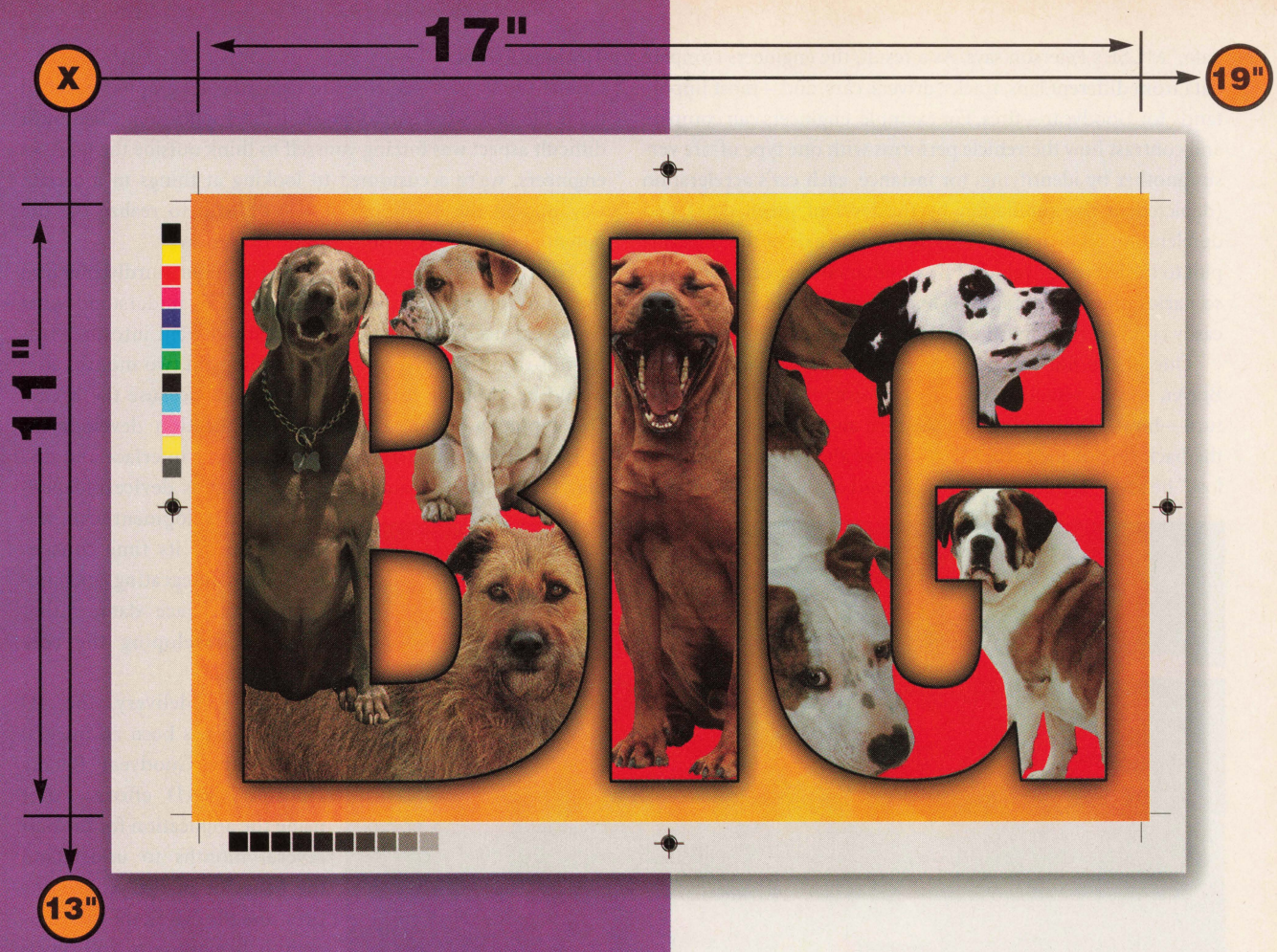
"The power of this application is through its 4D visualization. It ties the car's position on the track with all the data that's being measured. And you have the ability to move the car to where your point of interest is on the track. To me, those are the biggest deficiencies of the 2D charts," Brayer says. "It's like going from using and analyzing 2D data to almost playing a video game, with the vehicle traversing the track in 3D and the audio providing a fourth dimension of speed."

Goodyear's MUSE

To get more mileage out of the 2D Pi data, Goodyear teamed up with MUSE, with whom the tire manufacturer has had a previous relationship in R&D. Before the Pi information is viewed as an intuitive, graphical representation, Goodyear sorts it into a basic file format—a tab- and comma-separated spreadsheet-like form depicting a single car running a single lap on a certain track—using the tire company's proprietary MUSE Pi application running on an SGI (Mountain View, CA) Octane. Through a multisensory user interface developed by MUSE, the engineers can navigate their system to choose files for viewing, then select the "Go" button to translate the information into a visual representation. In the near future, Goodyear will also be running the MUSE application on a Windows NT system setup.

Although the scope of information collected is vast, there are some portions that are of particular interest to Goodyear, which are prominently displayed within the MUSE environment. These include a time stamp on the record, in-line acceleration (or deceleration), lateral (turning) acceleration, lap distance (the location of the vehicle within the lap), X and Y coordinates of the vehicle, and speed.

"Having all that information in a multisensory context enables the engineer to make dynamic associations among the



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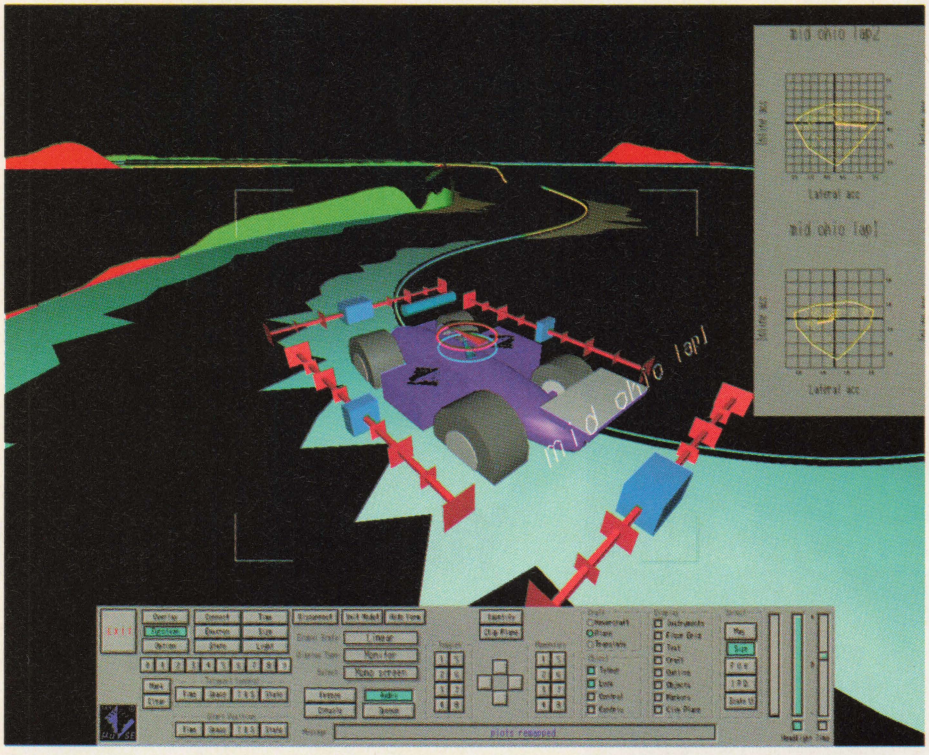
data," MUSE's Peterson says. As a result, the engineers compare data from different laps, tracks, drivers, cars, and—most importantly for Goodyear—tires. For example, engineers can compare and contrast how the vehicle performs with one type of tire versus another by identifying, for instance, each car's acceleration (depicted in the simulation by the level of green data) and deceleration (shown in red) on the vertical axis of the trackside plot to the left of the vehicle. "By simultaneously comparing two scenarios, the engineers can examine two cars side by side and easily contrast two laps of test data," he notes.

One of the most important areas of analysis, according to Brayer, was to visualize the car's performance as it executes a turn—how it slows going into the turn and accelerates through the back side of the turn. "That's where the races are won and lost," he says. "The idea is to stick as hard to the ground without breaking traction and to apply as much acceleration as possible. But you have to understand what the test behaviors tell you about the car, driver, and track in order to make good, solid decisions about changes you may want to make [in a tire's design]."

What's ideal about this application, says Peterson, is that without having to stop and think about the scenario, engineers can see at which point a car is executing a turn when reviewing the data. "It's right there. They see the track curving, and they see the track plot of in-line acceleration and the lateral acceleration," he adds. "Because of this contextual understanding, the engineers are able to concentrate on the relationship of the parameters they're trying to analyze."



Engineers can introduce many plotting instruments, such as the one along the upper right side of the image, which shows lateral versus in-line acceleration over time for each set of lap data. The yellow pointer extending from the center of each plot updates constantly, indicating the direction of acceleration at any given time. This plot helps engineers compare the performance of "follower" cars against the "leader," which is chosen by default as the front-running car.

Tireless Effort

One of the biggest challenges in using the 4D graphics resulted from the new work paradigm, not the application. "The most difficult aspect was forcing yourself to think outside the lines. As engineers, we're accustomed to looking at things in a certain way, and in the beginning, it was difficult to realize the full potential of using 4D visualization," Brayer says.

For the developers at MUSE, their major hurdle involved the short production period. Once MUSE understood what Goodyear needed from the application, it went into the project full-throttle, delivering the technology in two months so it would be available for the racing season. Because the MUSE Development System contains an application development framework with an array of automatic user interface and display capabilities, meaning the technology is device-independent, the development team was able to spend its time concentrating on integrating and presenting the race data, rather than on developing the core application.

After its delivery, the 4D application has been an integral part of the Goodyear Racing Division's R&D efforts. After using the application for the past several months to understand the behavior of the vehicle, the tires, and the driver, the tire company is beginning to call on its knowledge base of MUSE data (which looks at the vehicle equation). Combining the tire data from the MUSE application, especially the tire comparison information, with drivers' comments and proprietary vehicle modeling information, provides Goodyear engineers with "the direction as to what tire changes will improve the vehicle's performance," Brayer says.

"It's not a direct cause-and-effect situation," explains Brayer. "There are a lot of subtle characteristics we must consider when designing a tire, and the MUSE application lets us form relationships among those characteristics that can help identify a potential change." Using the collective data, the engineers then work to design tires that will achieve the desired performance parameters.

"The data or information you have is only as good as your ability to understand it," Brayer notes. "We feel this application has provided us with a step forward in that task. It's really not providing us with more information, but rather, we are able to get more out of the information we were already collecting."

Karen Moltenbrey is an associate editor of Computer Graphics World.

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fields of dreams

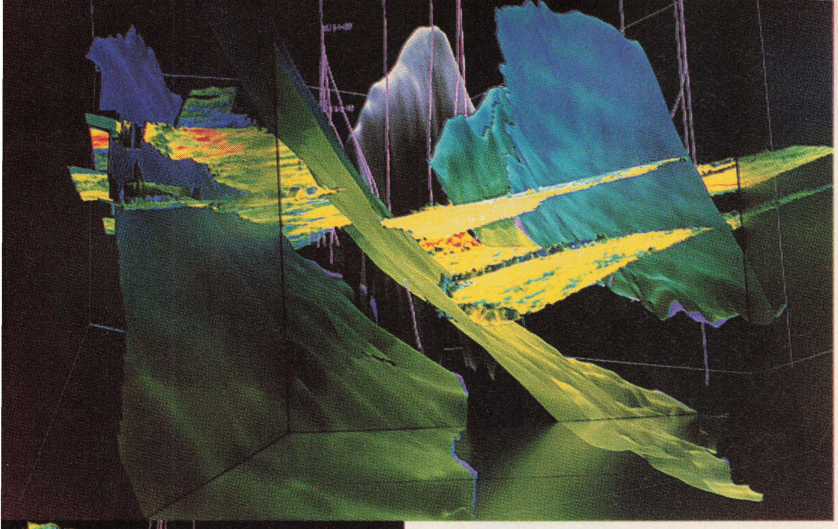
VR PROVES ITS WEIGHT IN (BLACK) GOLD FOR LOCATING HIDDEN OIL RESERVES

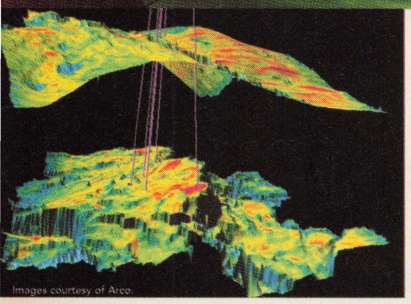
BY KAREN MOLTENBREY

SEARCHING FOR AN OIL RESERVE buried deep in the earth's crust is akin to looking for a needle in a haystack. However, by using sophisticated data visualization tools in a virtual environment, researchers can narrow their searches to the most likely locations, a key issue when the costs of drilling an exploratory well runs in the tens of millions of dollars.

Granted, advanced visualization techniques cannot enable experts to actually see oil deposits trapped far underground. But the same immersive technologies developed for analyzing other types of 3D data, such as medical images and fluid-flow dynamics, are proving to be equally valuable in locating the nooks and crannies that often contain hidden oil deposits, significantly increasing the chances of drilling a productive well.

Using immersive VR technology to view geological cross-sections (above), researchers can quickly and accurately detect where pockets of oil deep within the earth are most likely to be.





Potentially oil-rich fault areas appear as steeply dipping blue and green surfaces in a visualization of an Arco site in the Gulf of Mexico (above). The gray salt dome in back also indicates the possible presence of oil. At left, exploratory wells appear as pink vertical lines in an image of an Arco reservoir in the North Sea basin.

Visualization has long played a key role in oil exploration. In the late 1800s, pioneers searched for telltale surface features—outcroppings of shale, sandstone, or salt—below which oils tends to accumulate. But when the obvious reserves were depleted, finding oil became extremely difficult. That's when oil exploration went underground, as early geologists began to use seismic exploration, the technique of sending sound waves into the ground to listen for echo patterns that may indicate rock formations with oil trapped inside.

As computing power matured, that methodology evolved into 3D seismic surveys, in which numeric seismic data was collected and used to construct a picture of a subsurface region for a team of experts to review. "The problem was that we were looking at 3D seismic data as if it were 2D data, in cross-sectional lines—4000 to 5000 of them," says Michael J. Zeitlin, a Texaco fellow and manager of the company's global visualization effort in Houston. Reviewing the material line by line proved far too time-consuming, so the teams looked instead at intermittent lines of data and interpolated what was occurring between the intervals. "We collected all this data and then proceeded to ignore most of it."

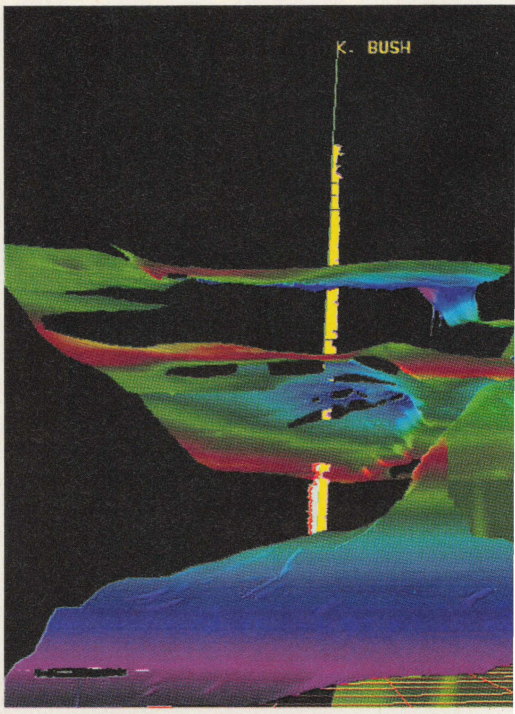
According to Zeitlin, that methodology was unacceptable for several reasons. First, geological changes indicative of possible oil reservoirs can occur within a given set of lines, which could easily be missed. Also, unlike 3D visualization, where the entire geological picture is presented, viewing intermittent 2D vertical slices of data provides only part of the geological picture, making it difficult to identify key geological formations, such as an old river-channel system, indicated by subtle seismic signatures. But perhaps most disturbing of all was the fact that oil companies were paying upwards of $15 million per site to collect 3D seismic information and were throwing away about 95% of it because they had no way to look at it all in an efficient way—until now.

"Using immersive 3D visualization technology allows me to look at all the data collected and lets me see, through pattern recognition, what's in all those 5000 lines [of cross-sectional seismic data], so I can focus on the task at hand—finding a well location," says Zeitlin.

Return on Investment

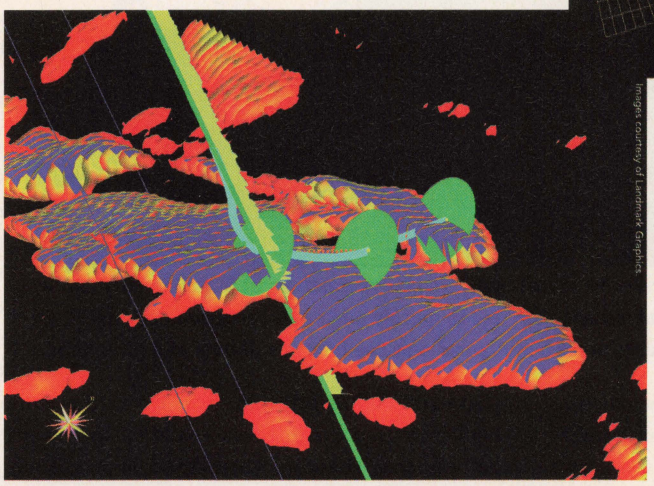
Using 3D visualization techniques has clearly paid off for users. According to Zeitlin, as a direct result of using the technology, Texaco has reaped "a magnitude in savings" by improving its drilling success rate. In less than a year after Texaco installed its first so-called "visionarium," a group of geologists and geophysicists used the center to identify where to drill a well off the coast of Nigeria, which led to one of the largest oil discoveries in more than 30 years for the company. According to Zeitlin, the asset team had spent two months selecting a location, but after viewing the data in 3D, the group decided against that decision and chose a new location to drill—after only two days in the center. "The first well they were going to drill would have missed its mark. They still would have struck oil, but it wouldn't have been [enough to make it a commercial viability]," he says. "So it's not just about hitting oil, but hitting a big enough zone that makes it commercially viable for development."

Arco in Plano, Texas, has reaped similar results using its multiperson VR environment. A year ago, an asset team reviewed plans for a well in UK waters of the North Sea. According to Geoffrey Dorn, Arco's director of visualization technology, the company's UK office designed the well based on typical input from geologists and geophysicists who didn't use immersive VR. But when the group arrived at Plano and reviewed its well-path design in the large-scale environment, in less than a half-day all agreed that the group's path was too risky. And in another recent offshore African project, Arco worked with a development partner whose interpretation of the seismic data differed markedly from Arco's. The companies debated for several months, but when both groups viewed the data in the visualization center, they reached an agreement in just one hour.



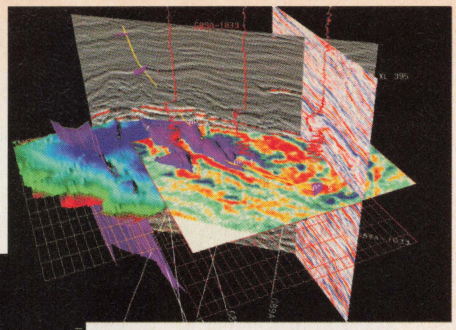
Landmark Graphics modified its OpenVision software to help Statoil display a well path in an immersive setting containing seismic, geological, and petrophysical data.

Because large-scale 3D visualization has produced such positive outcomes for exploration, companies are beginning to use the technology to review legacy 3D seismic and production data, to see if there are potential commercial reserves or pockets of significant value remaining. "There are many projects with hidden oil compartments that were bypassed because they were not deemed commercial. This technology may show those pockets to be commercial after all," says Zeitlin.



Images courtesy of Landmark Graphics.

Commercial software such as Landmark Graphics' EarthCube, used to produce this seismic image, is beginning to appear.



Using Landmark's OpenVision, Statoil can alter subsurface features and reservoir parameters to test working hypotheses.

Taking a Look

The jump from 2D to 3D large-scale visualization enables the oil company researchers to actually see and interact with an image created from a mathematical volume data set. The various software programs automatically color data points of similar numeric values within the set, in essence, transforming the mathematical data into abstract 3D colored shapes. The asset team can then look at groups of information with similar values and, by rotating them in three-dimensional space, can view the data as a whole.

"This allows me to look at tremendous amounts of data—20 to 30 gigabytes—at one time. Last year, more than 200,000 square kilometers of 3D seismic data was analyzed at Texaco using this technology. That's over 160,000 [2D cross-sectional] lines of seismic data interpreted in one year, and every geological formation inside those lines was looked at, as opposed to 10% or less [without 3D visualization]," Zeitlin explains.

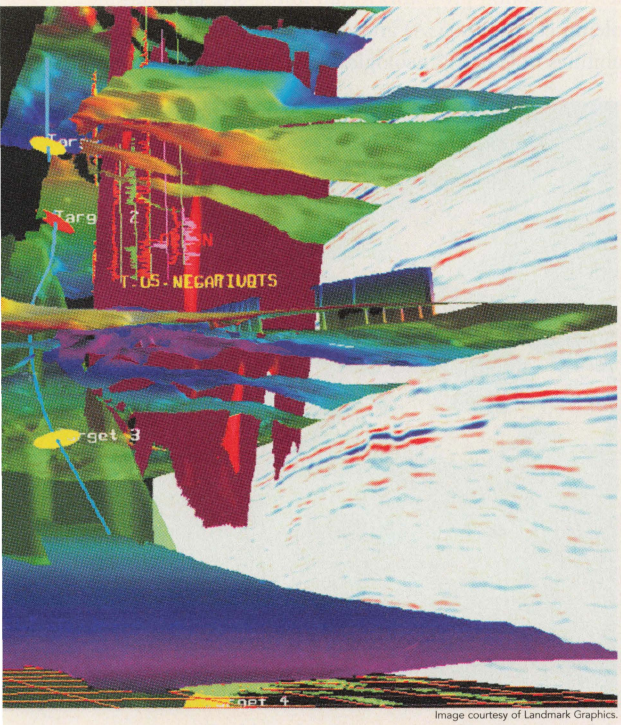


Image courtesy of Landmark Graphics.

Because the data set represents the underground regions of the earth as a volume, the teams can identify sandbars, sand channels, river channels, and beaches—where oil tends to collect—with much less effort, Zeitlin says. When the groups viewed the data in 2D cross-sections, they were looking at little pieces, making it extremely difficult to see the complicated geological features. "For example, we would be looking at a slice of a channel that cuts down into the geology, which is difficult to see with this old method, and we had to try to construct these geological patterns mentally, and usually we made mistakes or didn't see them at all."

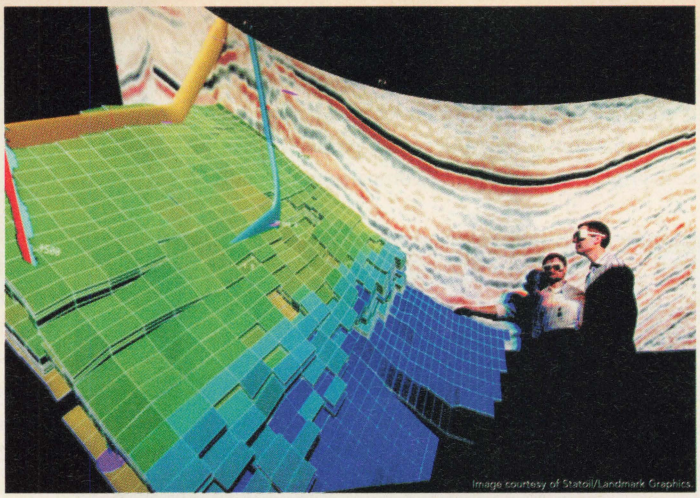
However, 3D viewing is just the tip of the iceberg. "We must produce an environment where we can interact with the information in real time. The result of that would be a strikingly powerful collaborative environment," Zeitlin says.

Using a large-screen visualization system has indeed created a new work paradigm in the oil industry. Previously, each specialist in the chain—geologists, geophysicists, reservoir engineers, drilling engineers, and project managers—would review and interpret the 3D seismic data individually, then pass the information along to the next person. This has led to a lot of costly mistakes, Zeitlin says, because no one in the chain wanted to redo his portion of the work if it was found to be suspect by another working further down the chain. In other instances, mistakes resulted from a lack of communication among the group members when one person would change data without informing the others. But with these new 3D environments, those specialists can more easily work together as a team, all looking at the same data at the same time—a process that could not be accomplished while using VR on the desktop.

And this workgroup atmosphere is not limited to a single site. Statoil in Stavanger, Norway, has installed large-scale visualization rooms at several of its key locations worldwide, enabling remote collaboration among the various teams. In fact, the company recently conducted a demonstration in which two teams—one in the US and another in Stavanger—could interact and change a data set, and both groups could view the changes in real time. "You can take advantage of your best people, irrespective of where they are located," says Adolfo Henriquez, director of subsurface integration technology.

This newfound collaboration has also led to substantial savings for users, com-

pressing the time required for seismic interpretation from six months to a week—or even days. Likewise, it has reduced the time to make the crucial decision of whether to drill from days to hours. "After a few days of work, I have a good idea of where to drill the well based on the visual cues within the data," says Zeitlin. For example, when a small group at Statoil used the company's visualization environment to review an updated oil-recovery project at Statfjord, Henriquez says, it was able to find 70 promising targets in a couple of weeks, instead of the months it would have taken otherwise.



Immersive 3D visualization enables researchers at Statoil to view entire areas of seismic data and to quickly and easily recognize patterns. Previously, asset teams could only see intervals of data at a given time.

According to Henriquez, his company is now able to make much better overall decisions concerning oil prospects. For instance, using 3D visualization, Statoil can more accurately determine the company's overall costs of extracting oil and decide whether it is cost-efficient to drill in a certain location because of the geology present. Once the decision to drill is made, the 3D data can then be used to determine the best angle when approaching the location to find the "sweet" spot of the recovery zone. Finding the most permeable area where the oil will flow most quickly will reduce production costs.

Drilling fewer, more productive wells can have a significant environmental impact, as well. "We'd like to be in a situation where, when we're done drilling, you'd never know we were there," Zeitlin says.

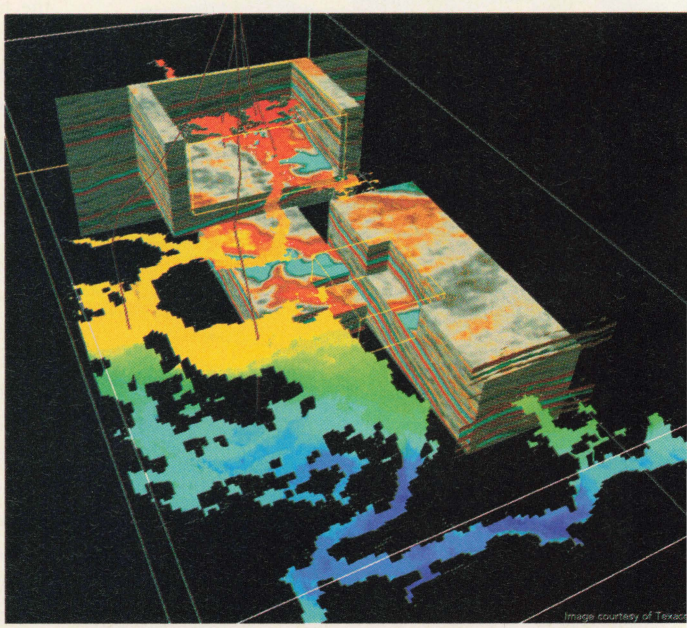
A Quantum Leap

Using immersive technology to view 3D data is hardly in its infancy (see "Getting the Big Picture," page 41), but using it to explore oil reserves is a fairly new concept. What helped push VR out of the laboratories and into mainstream industries such as oil was a confluence of database technology, increased memory, and better hardware/display systems, according to Linda Jacobson, virtual reality specialist at SGI in Mountain View, California. The database technology evolved to where it could handle large data sets, and the price of computing power declined, making the technology more affordable. Also, software engineers and the interface community began developing applications and devices to capitalize on this new frontier.

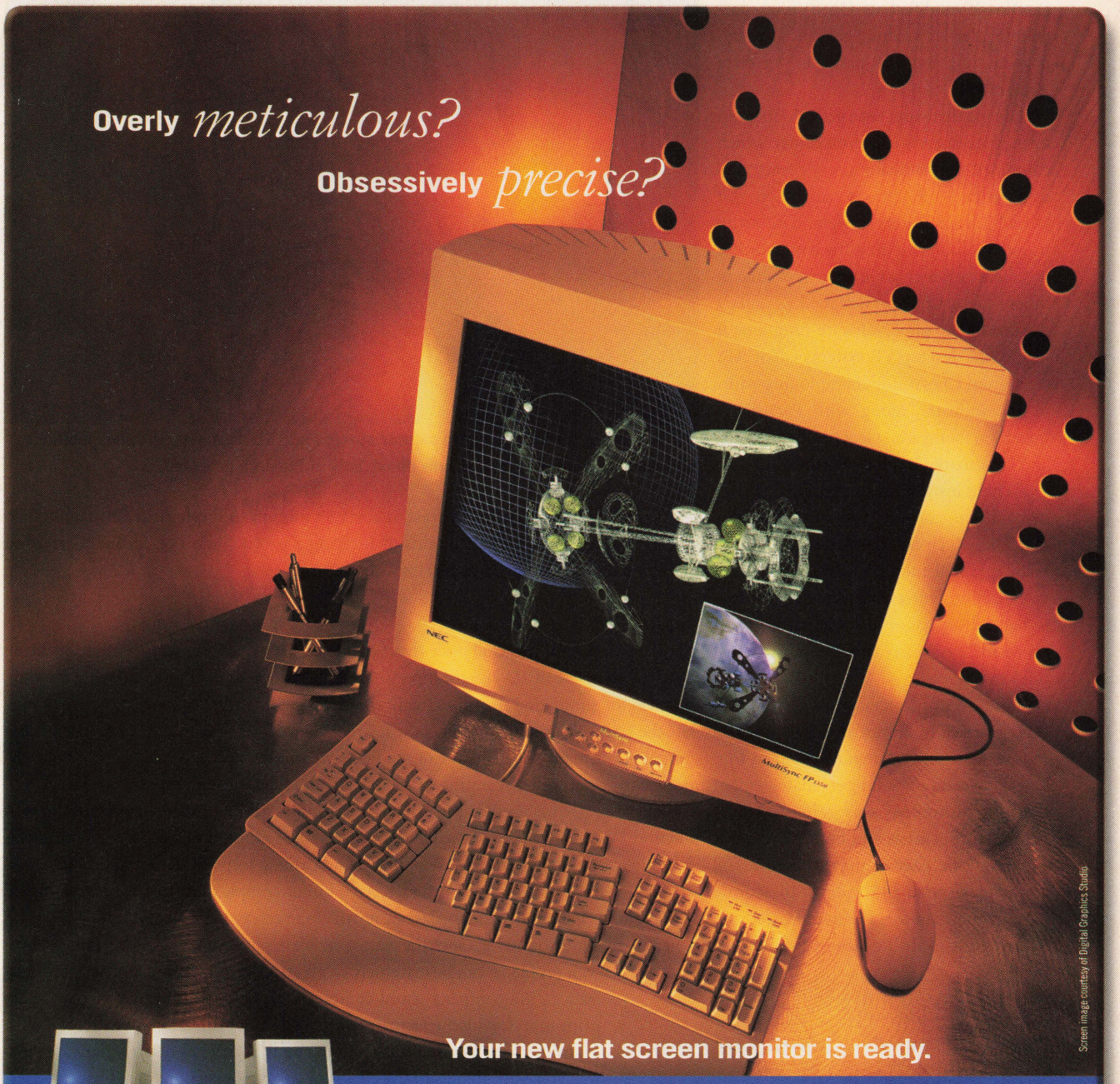
Although several oil companies began using desktop VR systems in the early 1990s to view small portions of 3D seismic data, it was not until 1997 that groups of researchers began to collaborate while viewing extremely large (terabyte-size) seismic data sets. Pioneering this technology in the oil industry was Texaco's Zeitlin, along with Arco's Dorn. After working with large-scale visualization technology for more than a year, Zeitlin in November 1997 opened Texaco's first visualization center in Houston, where up to 30 people can gather to view large 3D seismic data sets using a projection system. Dorn, on the other hand, chose a smaller environment (similar to the University of Illinois' CAVE) that can accommodate up to 15 people, opening the facility in May 1997.

While both companies chose the same hardware—an SGI Onyx2 InfiniteReality system—finding appropriate software was practically impossible, forcing each to write its own programs in-house. So when construction of the Texaco facility began, Zeitlin hired programmers to develop the software applications "that would take advantage of what the facility could do." At Arco, Dorn and his staff adapted proprietary software from their desktop systems to run in its environment. Just recently, the company developed some additional applications in-house and is working with outside vendor Paradigm Geophysical (makers of the VoxelGeo desktop program) for an immersive application. Arco, along with Chevron Petroleum (La Habra, CA) and others, have formed a consortium to incorporate VR capabilities in GoCAD, geological CAD modeling software from T-Surf.

One year after Texaco and Arco began using large-scale virtual technology, Statoil also took the plunge by installing a projection-screen system powered by an SGI Onyx2. But that company took a different route for applications. "As an oil company, we are not in the business of writing software to produce these programs. Our focus is to buy, not build. Therefore, it is important that we have commercial vendors that can supply the necessary software," says Henriquez. "So we established a partner-



A proprietary visualization program developed by Texaco automatically colors data according to numeric density values, thereby transforming seismic data into abstract 3D shapes for more intuitive analysis.



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ship with SGI and Landmark Graphics, and Landmark modified its OpenVision program to display seismic, geological, petrophysical, log, and well-path data in three dimensions."

During this same time period, Chevron opened its first visualization center, which combined the company's proprietary wall displays and VR options run by an SGI Onyx2 InfiniteReality system. The setup proved so successful that the company has installed commercial display systems in other offices. Chevron designed its centers to run on the same software programs it uses on its desktop VR systems—GoCAD, a program Chevron is championing within the industry, along with Paradigm's VoxelGeo software, GeoQuest's GeoViz, and Landmark Graphics' EarthCube.

"These installations are driven by user demand for collaborative work environments in which familiar software will run. With minimal training, users walk into a visualization center and immediately begin to take advantage of the large-screen environment," says Chevron research scientist Bill Kowalik.

Because until recently large-scale VR was practically unheard of in the oil industry, all three companies had to find a way to convince upper management that this technology was going to transform their business, and that the risk was worth taking. According to Zeitlin, oil companies spend $15 million to acquire 3D seismic data for a single project and $40 million to drill a deep offshore well that could likely be dry. In contrast, it costs $3 million to implement this technology that likely would improve the odds of locating a profitable oil reservoir. "One good project pays for the entire technology," he says.

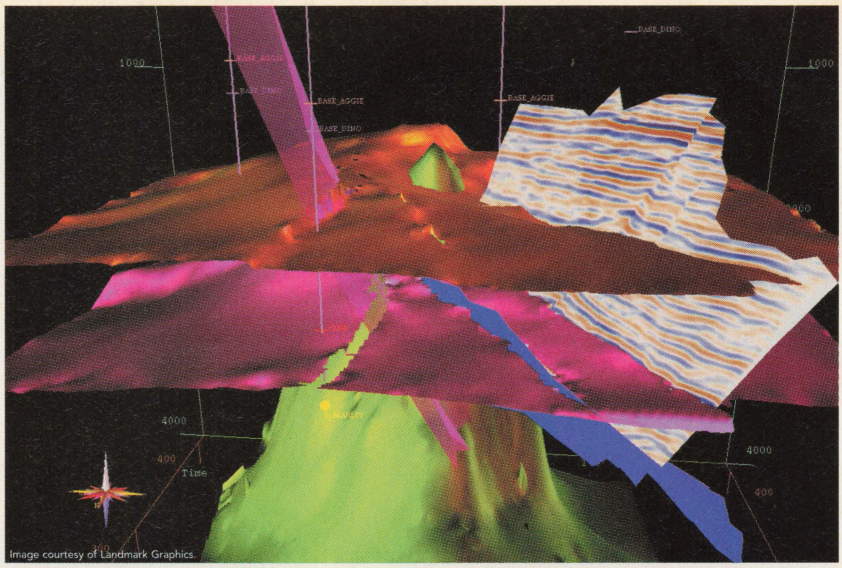

Image courtesy of Landmark Graphics.

VR technology transforms entire seismic surveys into 3D data sets. Previous methods allowed researchers to look at only about 10% of the data collected.

A Well-Laid Plan

For the past several years, oil prices have remained flat, which was an incentive for the oil industry to invest in 3D visualization technology, not only for finding possible reserves, but also for simulating the oil-extraction process. "Using this technology, we can simulate the reservoir flow and predict how it will produce over time to give us an idea of economic performance over the life of the field," Zeitlin says. Texaco is also using the technology to review other scientific data, such as fluid flow through pipes.

Likewise, Arco is applying its 3D visualization capabilities to review reservoir production. "We haven't even scratched the surface of the range of problems where this really applies, from exploration, development, and drilling to plant design and CAD/CAM applications," notes Dorn. For instance, Arco builds complex facilities for extracting oil and gas and floats them to its Alaskan north slope reservoirs during the warm season when there is little or no ice. Once the platforms are in place and operational, any unforeseen problems can be extremely costly to correct. By using large-scale visualization, the company could conduct a virtual walk-through of the facility prior to it leaving the factory, reducing design problems downstream.

Immersive 3D visualization in the oil industry has taken a giant step forward recently, thanks to the efforts of a few pioneers. In turn, the early users have drilled fewer dry wells and found more large oil reserves. "The industry has half the number of employees today as it did in 1986, yet the amount of production and oil discoveries have more than doubled. This technology allows us to keep our margin, at least for a short time, with fewer people and helps us survive in a low-price environment," Zeitlin says.

But this is only the beginning. To delve further into the depths of the seismic data, "we collaborate competitively" by growing the technology to handle even larger data sets that will provide an even better snapshot of the geology, Zeitlin says. In turn, this will create a greater need for computer memory and speed, as well as relevant commercial software, which is just beginning to appear. "Our goal is to have no dry holes and to develop the technology to allow us to know, even before we drill, where the oil is, how much oil is there, and how much of it we will be able to produce," he says.

Karen Moltenbrey is an associate editor of Computer Graphics World.

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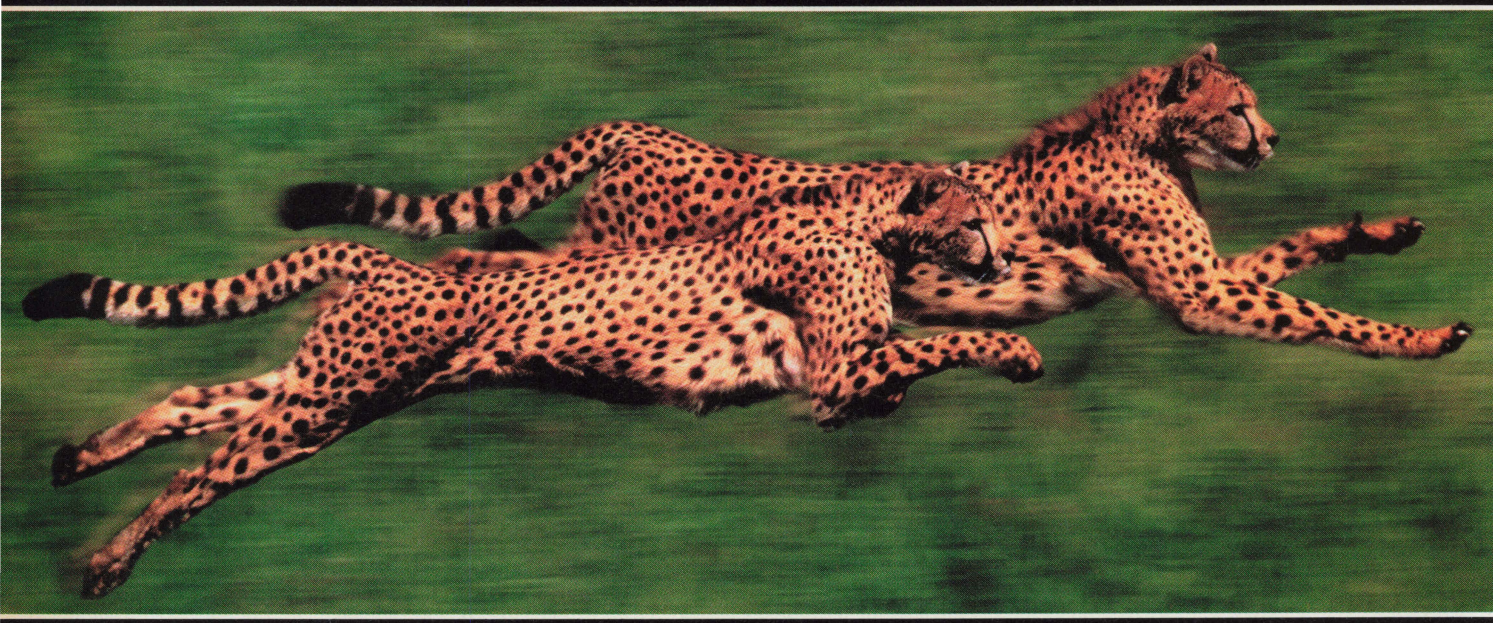

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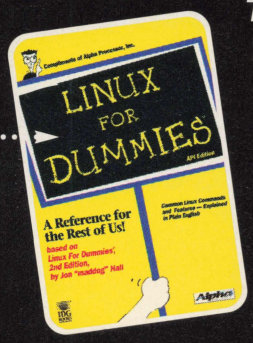

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Getting the Big Picture

LARGE-SCALE PROJECTION DISPLAYS BRING 3D MODELS AND SIMULATIONS TO FULL-SCALE LIFE FOR MULTIPLE USERS

BY DIANA PHILLIPS MAHONEY

When it comes to immersive displays, bigger is better. In fact, today's large-scale display environments are being hailed as the first truly practical facilitators of virtual reality. They bring together some of the hottest trends in computer graphics, including real-time interaction with high-resolution data sets, group immersion into virtual environments, and collaborative design and review.

The market for large-screen visualization displays has expanded considerably over the past few years, as improved projection techniques and high-end graphics processing power have become available. While the products in this category vary considerably in terms of size, shape, technology, and application, all share a common vision: to enable big views of big data by big groups of people. Moreover, they all are the focus of aggressive marketing campaigns to convince customers that the hefty price tags of these products (from $150,000 to $500,000 and beyond) are reasonable, given the potential return on investment.

Subtle details of a geophysical visualization can't be missed when the high-resolution data looms larger-than-life on a 25-foot semicircular screen from Trimension. This SGI Reality Center setup offers researchers a 160°x40° field of view.

The proliferation of large-screen display technologies has evolved in direct response to the need for new ways to exploit the ever-bigger and better data that software and hardware advances of the past few years have enabled. For example, now that design engineers have the processing power they need to create and interact with highly detailed digital mockups of cars and airplanes, they can imagine the value of doing so at full scale in the company of colleagues and clients to further streamline production processes. Similarly, pharmaceutical researchers who are satisfied with the speed at which they can model the complex molecular mechanisms of drugs can imagine the efficiency gains to be had by broadening the display window to include the entire scientific data set, rather than just a portion of it at a time.

Mechanical design and scientific visualization are just two of the many application areas that are beginning to reap great rewards from this display genre. Others include architecture, industrial design, urban planning, and oil and gas exploration—the current poster child for the technology (see "Fields of Dreams," pg. 33). Each area is well suited to the technology for a number of reasons. First, each involves interacting with volumes of data, and while that can be done on a smaller display, it usually can't be done "in context." As in pharmaceutical design,

Industrial designers can evaluate full-scale digital mockups of car designs using a semi-circular Trimension display driven by SGI workstations.

© 1999. Newport News Shipbuilding

Designers, engineers, and administrators at Newport News Shipbuilding can review mechanical designs simultaneously in a GVR-120 VisCenter from Panoram Technologies.

interacting with large data sets on small displays requires viewing subsets of the data. On the big screen, in contrast, the user is able to see how any one area of interest fits into the big picture.

Additionally, these applications typically require multidisciplinary collaboration. Architects, for example, don't work in a vacuum. They work in concert not only with the client, but also with developers and contractors and perhaps, with city planners and government agencies. Imagine the benefit of being able to share conceptual models for a proposed structure with all the parties involved in its development. In such a scenario, an HVAC or electrical subcontractor might be able to identify problems with the proposed layout, then the architect could make the appropriate adjustments in real time, and the client could evaluate the aesthetic effect of such changes. It's even conceivable that all the parties may not be located under the same roof. They may be in geographically dispersed visualization facilities, yet be immersed in the same environment. Under normal operating procedures, the back and forth interaction among the various interests would require generating multiple iterations of the design, adding many weeks and dollars to a project.

A Growing Market

As the market potential for large-scale display technologies becomes more apparent, the list of product offerings in this category grows. Because these products generally do not represent a single "new" technology, but rather are an integration of many new and existing technologies, the vendor community is a disparate lot. It includes VR display vendors, who bring to the table what they've learned about the representation of virtual worlds via "personal" VR interfaces, such as headmounted displays, and graphics workstation vendors who know how to harness computer processing power to generate high-quality, real-time representations of large data sets. It also includes vendors specializing in technologies for controlling the output of multiple projectors to create a seamless, unified display, as well as companies specifically geared to the development of unique projection technologies. Though competitive with each other, many of these vendors also complement each other by licensing a technology or using hardware developed by one of the other companies and incorporating it into their own offerings.

Large-scale projection displays can be loosely broken down into two categories: immersive "rooms" and presentation "walls." The spatially immersive displays surround users with a 3D visual and audio scene, which, with the help of tracking and navigational devices, responds to the user's orientation and action. Display walls, in contrast, are visualization systems that use either front- or rear-projection techniques to display high-resolution imagery onto expansive flat or curved screens. Not only do rooms and walls differ physically, they also serve different needs. Immersive rooms are best suited for interactive virtual simulations, while display walls are typically used for group presentations and collaborative design reviews.

Many of the "rooms" are modeled after the CAVE (Cave Automatic Virtual Environment), a multi-user system developed at the University of Illinois in 1992 and now marketed by Pyramid Systems. The CAVE consists of three rear-projected screen walls and a front-projected floor. Wearing stereo glasses, up to eight users can experience the environment simultaneously, though only one user is tracked and is the navigator of the scene.

Since the CAVE's development, several competing room systems have been introduced, including the new Immersive WorkRoom from Fakespace and the VR-Cube from TAN Projection Technologies. The Immersive WorkRoom extends immersive VR capabilities to a collaborative setting. While Fakespace has seen much success with its personal VR devices, particularly the BOOM (Binocular Omni Orientation Monitor) interface, such products are ill-equipped for group consultation.

"The BOOM allows individuals to be immersed in a virtual environment," says Fakespace president Mark Bolas. "But now that the price of projectors is coming down to where it's no longer prohibitively expensive to surround the display with them, and high-resolution computer graphics are a lot cheaper to generate, we can afford to create an environment that gives more people access to the data at the same time."

The Immersive WorkRoom, which is similar to the CAVE with a 10x10x10-foot configuration, offers the advantage of easy integration with Fakespace's interactive and navigational tools, including its Pinch Gloves and NeoWand.

A full-scale air-traffic control tower simulator with a custom 360° visualization display is at the heart of NASA's new test facility. The virtual replica will help researchers solve potential air and runway traffic problems at commercial airports.

An R&D innovation that sets the Fakespace product apart is the Duo system, which uses custom shutter glasses to present two independent views of the same data. "Initially, we assumed the system would be used to provide two people with unique perspectives on the same data," says Bolas. "Then some interesting applications cropped up. For example, a client could be looking at a finished model of a house, while the contractor is seeing 2x4s and cabling. If the client asks for a change, the contractor can see right away whether it's feasible."

TAN's VR-Cube is also an outgrowth of the CAVE. The company recently introduced the first commercially available six-sided display, which requires the projection of images onto four walls as well as the floor and ceiling. Unlike the CAVE and Immersive WorkRoom, which utilize third-party projection-blending technology, the VR-Cube relies on TAN's own system, according to Steve McConkie, systems engineer with TAN's partner, Carpenter Communications.

Another system that fits into the immersive-room category isn't really a room at all—it's a dome, called the Vision Dome from Alternate Realities Corp. (ARC). The Vision Dome differs from most other spatially immersive displays in that it offers a single-projector solution. Specialized optics in a patented 3D lens enables the single projector to display high-resolution digital data into a 360°-by-180° virtual environment. The advantage of a single-projector system over competing systems that require multiple projectors and multiple screens is cost-efficiency, says Mike O'Dell, president and CEO of ARC. "The development costs for multiple-screen, multiple-projector systems are higher because you have to configure the application to drive all of the screens and projectors." And because the Vision Dome libraries support OpenGL standards, he says, "anything developed in OpenGL runs out of the box without modification."

Vision Dome's spherical display mimics our natural perceptive capabilities, says O'Dell. "We all see things in a 180° field of view. Replicating that is critical to many applications. When you're viewing an automobile in the Vision Dome, the car is life-size, not a picture on a screen with a 60° field of view." To eliminate distortions from the curvical display area, the system employs distortion-correction libraries.

Spatially immersive displays, such as the Fakespace Immersive WorkRoom (left), are best-suited for applications in which users can benefit by being surrounded by and interacting with their data. Display walls, like the Fakespace Immersive WorkWall (below), are ideal for collaborative design review and analyses of full-scale digital models.

PROJECTION-BASED IMMERSIVE DISPLAY SYSTEMS

Vision Dome
Alternate Realities Corp.
Durham, NC
www.virtual-reality.com
infoNOW 76

Immersive WorkWall, WorkRoom
Fakespace
Mountain View, CA
www.fakespace.com
infoNOW 77

GVR120, PanoWalls
Panoram Technologies
Sun Valley, CA
www.panoramtech.com
infoNOW 78

CAVE
Pyramid Systems
Novi, MI
www.pyramidsystems.com
infoNOW 79

Reality Center
SGI
Mountain View, CA
www.sgi.com/reality center
infoNOW 80

TANorama, VR-Cube
TAN Projection Technologies
Dusseldorf, Germany
www.tan.de
infoNOW 81

Reality Rooms, V-Domes
Trimension
West Sussex, UK
www.trimension-inc.com
infoNOW 82

Walls of Wonder

Because they're aware that different applications have different display needs, many of the projection-based display vendors offer a range of solutions from both the room and wall camps. The TAN VR-Cube, for example, can be configured with four or five sides, rather than six, to suit space, cost, and application needs, and both TAN and Fakespace offer display wall products. TAN's panoramic display technology, called TANorama, comes in curved or flat-screen configurations and rear or front projection.

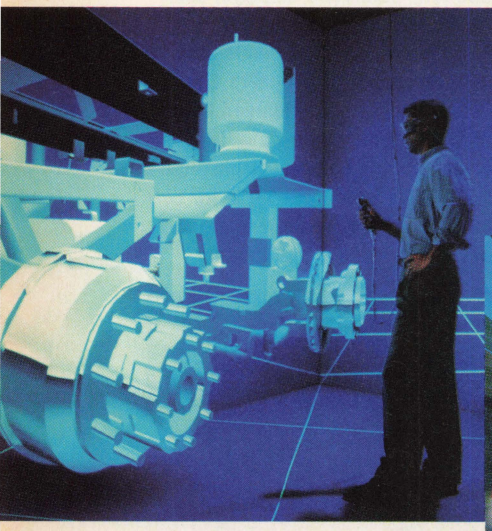
The Fakespace wall, called the Immersive WorkWall, is a rear-projection system that utilizes 8x16- or 8x24-foot screens. The system is scaleable, says Bolas, "so you can add screens where you need them to represent the model. We have a client talking to us about using VR for semi truck design. That's obviously going to require a huge display to get it to scale."

Other vendors include Trimension, known for its theatrical-type curved-screen facilities, and Panoram Technologies, recognized for its patented hardware-based edge-blending technology. In fact, many of Panoram's "competitors" license its edge-blending technology for use in their own products. Unlike TAN, Panoram doesn't retrofit the projector technology to blend the

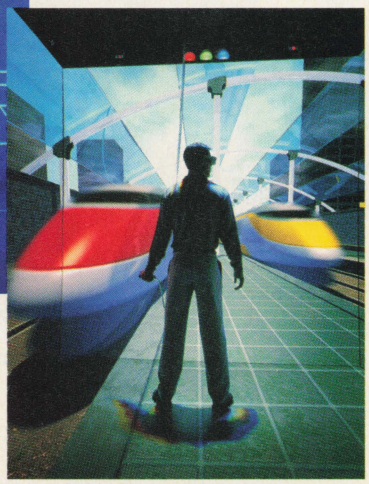
edges of the projector output. Instead, it relies on off-the-shelf projector technology, the signals from which are run through the hardware with a minimal delay (220 nanoseconds), enabling real-time display without perceptible lag.

Panoram is a pioneer in the visualization display arena. The company was the first to market a turnkey immersive display setup—the GVR 120. "At some point, we realized that people were buying our equipment and not knowing how to set it up and not understanding the technology. With the [GVR 120], that was no longer an issue," says Larry Paul, director of product development.

Panoram, like many of its competitors, now offers a variety of flat- and curved-screen systems using front and rear projection. The choice of one setup over another has less to do with the chosen technology than with the chosen application. "If a company wants to display a car, it will want to look at it on a flat screen to get an undistorted 1:1 projection," says Paul. "If they want to walk right up to the display, they'll want rear projection because with a front-projection system, walking up to the screen would block a projector and occlude part of the image." Front projection might be called for when space when space for the system is limited.



An engineer can explore a virtual automotive suspension in a Pyramid CAVE environment.



A virtual model of a European bullet-train station displayed in a Pyramid CAVE could almost pass for the real thing to a user experiencing the 3D environment with the help of positional tracking and stereo shutter glasses.

Curved screens are ideally suited to simulations and fly-throughs in which there is a lot of data to be experienced. The Panoram curved screens offer a 120° field of view because, says Paul, that curve provides the best functionality for customers. "If we had a 180° curve system, which we could certainly do, it becomes difficult to sit and watch because there's so much head turning. With the 120° curve, users are able to look left and right as they would in real life, and it's not uncomfortable." Of course, the ideal degree of curve can be application-driven In fact, TAN is developing a 360° screen for an air-traffic control simulation to mimic the real world as closely as possible.

Big curves and big screens mean lots of projectors and lots of sweat and tears to synchronize the output. Achieving a seamless display is one of the challenges of large-scale projection. It typically involves overlapping the edges of the multiple projected images and using edge-blending techniques to seamlessly merge the images. This involves programming one area to fade out as the other fades in. "It sounds easy, but it's not entirely obvious, and it changes depending on what you're projecting," says Adam Finkelstein, a researcher at Princeton University.

Big Challenges

Among the problems Finkelstein and his colleagues are looking at is the calibration of multiple projectors. "Right now, we have this big rack of projectors that we line up by eye. What we'd really like is an automatic process to do the fine tuning—move this one a little to the left, zoom this one out a bit, and so forth—so they line up perfectly. We'd rather not have this be a mechanical process, because that's not very accurate." So the researchers have developed a camera that zooms in and out on the display and then, based on what image is onscreen, instructs the projectors to simply adjust what they're showing.

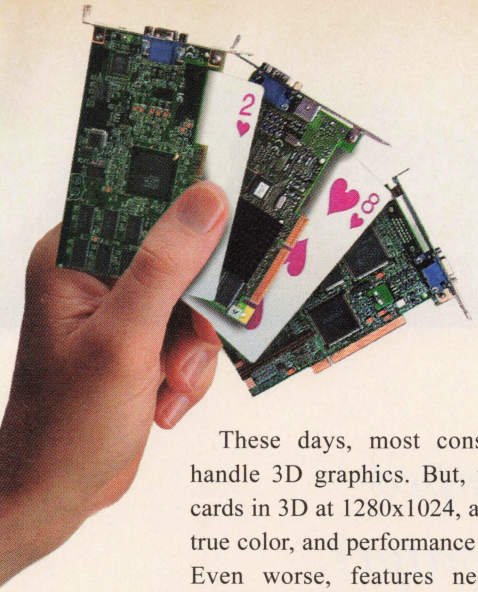
In addition to the technical challenges of implementing large-scale displays, a number of conceptual issues must be addressed as well, says Linda Jacobson, virtual reality specialist at SGI. "Now that the designer's canvas has expanded 100-fold, a design can be larger-than-life. This means that any [imperfections] in the design that weren't evident on the desktop monitor will be gigantic on the big screen. So attention to detail becomes even more critical."

Another major question is whether applications are being developed to take adequate advantage of VR technologies, says Jacobson. "There's a dearth of applications that truly leverage VR," she says, and without them, the market for these displays will remain fairly narrow and specific. "The world needs more commercial software applications that run, without code modification, in these environments."

In an effort to support the development of such applications, SGI developed what it calls the Reality Center, through which company consultants work with customers to design a display solution powered by SGI computers to suit their needs, then subcontracts services to the appropriate vendors to fulfill the vision. The company has established technology partnerships with most of the large-scale display vendors and re-sells and supports their products under the Reality Center moniker.

An awareness of the potential return on investment these display systems can effect can also go a long way toward bringing the technology to more users. "The big automakers and oil companies generate huge profits from their investment in these immersive and collaborative visualization technologies," says Jacobson. "They may have to spend a lot on their facilities, but they reap great returns and recoup their investments, sometimes in a matter of weeks."

Diana Phillips Mahoney is chief technology editor of Computer Graphics World.



Cards for play.

These days, most consumer-level cards can handle 3D graphics. But, try using one of those cards in 3D at 1280x1024, at a high refresh rate and true color, and performance plummets dramatically. Even worse, features needed for professional applications like antialiasing, alpha blending, and stencil planes may not even be supported. And, while most of these cards claim OpenGL readiness, they haven't been tested with key applications. If you're a professional using 3D CAD or animation applications, you need a card that means business.

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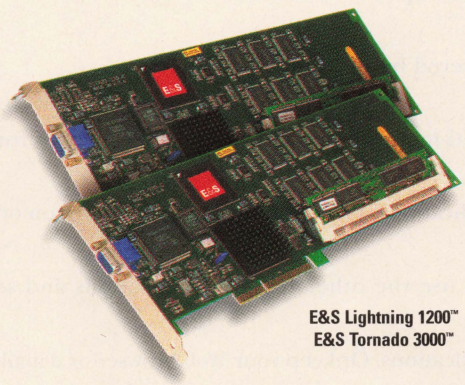

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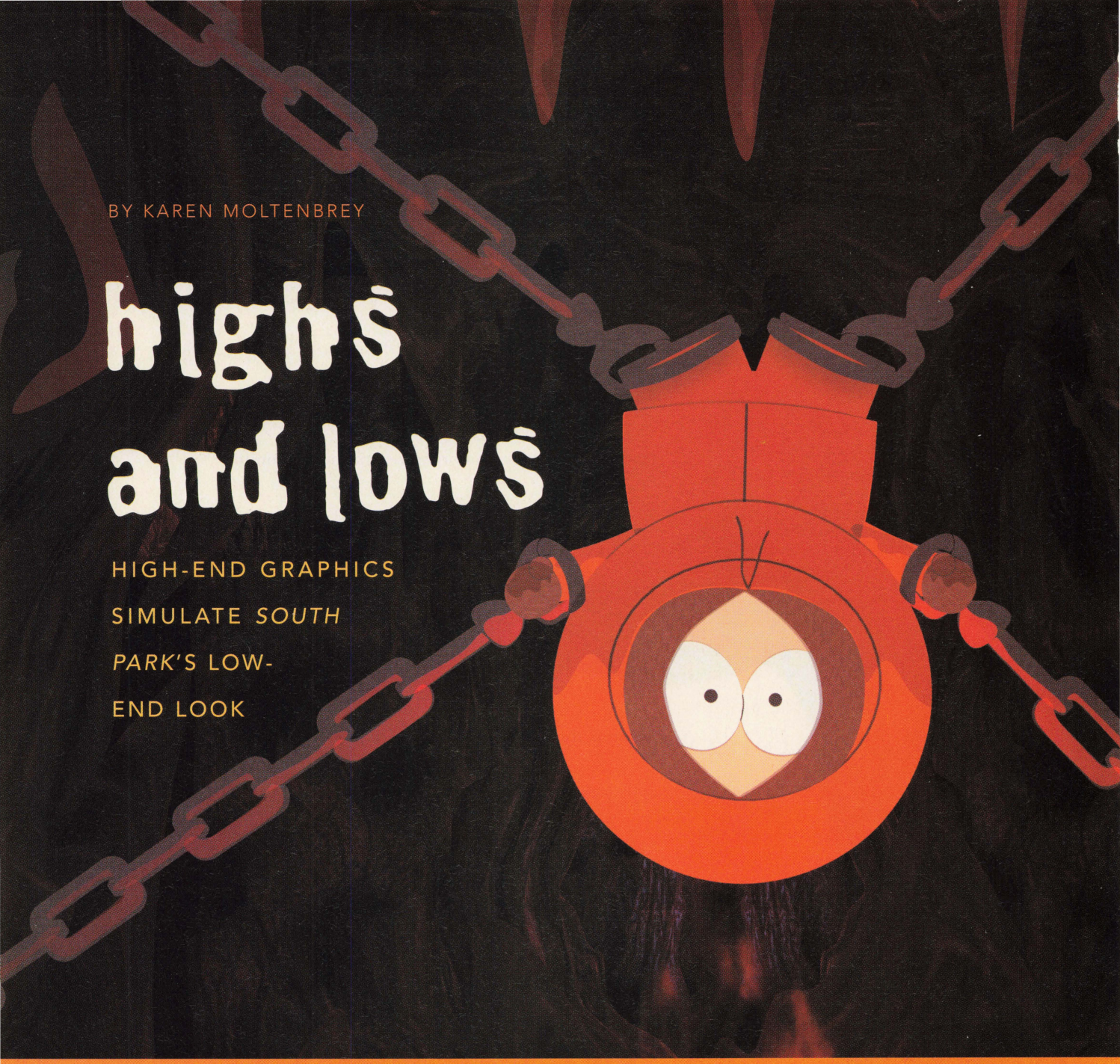
BY KAREN MOLTENBREY

highs and lows

HIGH-END GRAPHICS SIMULATE *SOUTH PARK*'S LOW-END LOOK



Without a doubt, Paramount Pictures' animated feature film *South Park: Bigger, Longer & Uncut* is atypical. Because the animators used high-end 3D tools to simulate the simplistic, two-dimensional look of the characters and most of the backgrounds, the movie's graphics (like the plot and dialog), stray far from what most would consider the norm.

The movie, like Comedy Central's hit television show *South Park*, features characters that are supposed to resemble construction-paper cutouts. Although the animation team for the *South Park* television pilot used actual paper characters, the group soon learned that the most efficient way to achieve a paper look for the show, and now the movie, was to create 3D models using Alias|Wavefront's (Toronto) PowerAnimator software. "Most of the movie is 2D-looking, like the television show. PowerAnimator gave us the best texture mapping to replicate construction-paper texture and the natural shadows you get when you place paper underneath a camera stand," says Eric Stough, animation director at South Park Productions, producer of the series and movie.

PowerAnimator also proved extremely efficient during the 11 months the animators had to complete the film, enabling the group to re-purpose some background elements from the series, such as the characters' classroom, South Park Avenue, and some houses. "But we had to apply higher-resolution shaders and filters so they looked more like construction paper and didn't pixel [break apart] in the larger size," Stough notes.

©1999 South Park Productions and Paramount Pictures.

Artists at South Park Productions modeled and animated the 2D *South Park* characters using PowerAnimator 3D software from Alias|Wavefront.

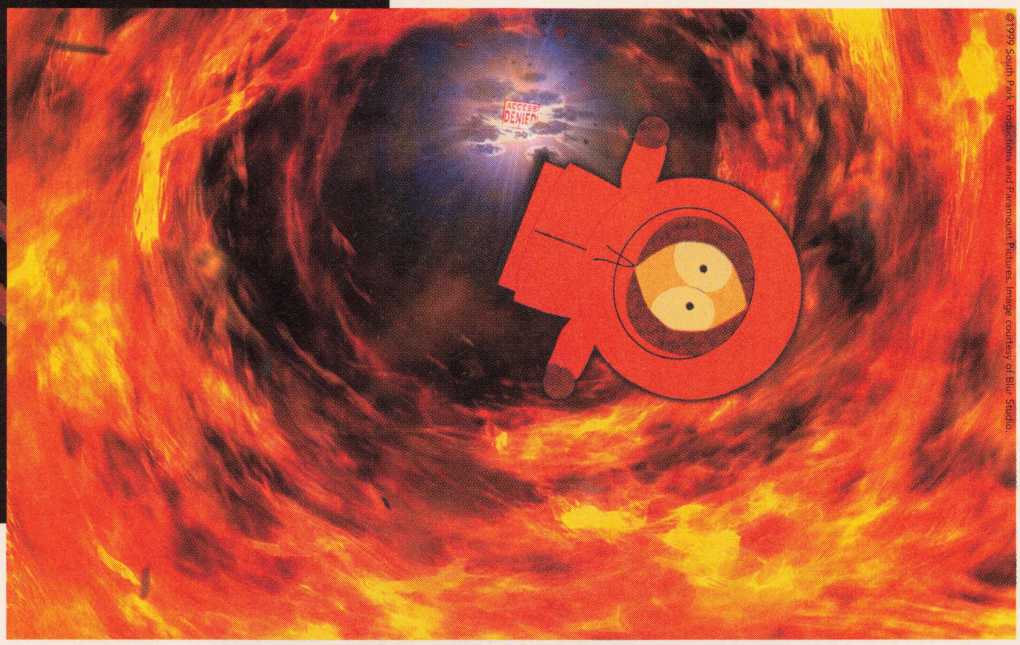
The power of PowerAnimator, however, proved most useful in creating the afterlife depicted in the movie following Kenny's untimely demise and his brief visit to heaven and his longer stay in hell. "We wanted to establish the 'grandeur' of hell," Stough says. "To make things appear realistic in the television series, we use still photographs. For the movie, we created a realistic environment by *animating* realistic images."

Kenny's death in the film is hardly unexpected. In each episode of the weekly television series—which chronicles the life of four third-grade boys living in UFO-infested South Park, Colorado—he dies in some kind of horrible accident.

After Kenny is killed in the movie, he goes to hell, where he discovers Satan and his side-kick/lover Saddam Hussein trying to take over the world. Meanwhile, the South Park gang must save their town. After the boys are heard repeating raunchy words and phrases learned from an R-rated Canadian movie, South Park's outraged citizens launch a censorship campaign—and a war against Canada.

©1999 South Park Productions and Paramount Pictures.

While most of the characters and the background images in *South Park* are 2D-looking, the backgrounds in the hell sequences are far more elaborate. Blur Studio, which created some of the scenes, wrote a sophisticated environmental-effects plug-in to 3D Studio Max to achieve realistic CG fire.



©1999 South Park Productions and Paramount Pictures. Image courtesy of Blur Studio.

Not-So Model Characters

The characters and backgrounds for the movie were originally created in Corel Draw by storyboard artists, who exported the 2D curves as Adobe Illustrator files. The technical directors (TDs) then imported the curves into PowerAnimator, running on SGI (Mountain View, CA) O2 and Octane workstations, and assigned textures from a large palette of construction paper-like surfaces (created from scans in Adobe Systems' Photoshop). Using PowerAnimator, the TDs separated the Illustrator information into 3D layers and groupings of geometry, so the characters' eyes, hair, noses, and mouths, for instance, were layered and grouped like "layers of construction paper glued together," Stough says.

To animate the characters, the artists used PowerAnimator's expression sliders, which are mathematical formulas that control the image geometry's visibility. For example, when the head slider is set at 0.5, the flat character is facing frontward; if the slider is moved to 0.6, the front of his head becomes invisible and the right side of his head becomes visible, as if the paper-like character suddenly turned his head to the side. The same sliders were used to lip-sync the characters. To render the images, the group again used PowerAnimator running on South Park Production's SGI machines, along with some additional help from Digital Domain's SGI render farm.

What Goes Up...

Although most of the 3D models in the film resemble 2D paper cutouts, the background imagery shown in the heaven and hell scenes is far more elaborate. To create Satan's domain, animators at South Park Productions maintained a large portion of the simplistic 2D look but "punched" holes in the 2D-like background, behind which they created an elaborate 3D world that included realistically animated fire and glowing lava.

An impressive sequence chronicling Kenny's descent from heaven to hell was created by Blur Studio, a Venice, California, special-effects house, using newly developed propri-

©1999 South Park Productions and Paramount Pictures.

PowerAnimator proved to be the most efficient tool for creating the movie's style of construction-paper stop-motion animation. The software's texturing and shadow features enabled the artists to achieve the characters' 2D paper cutout look.

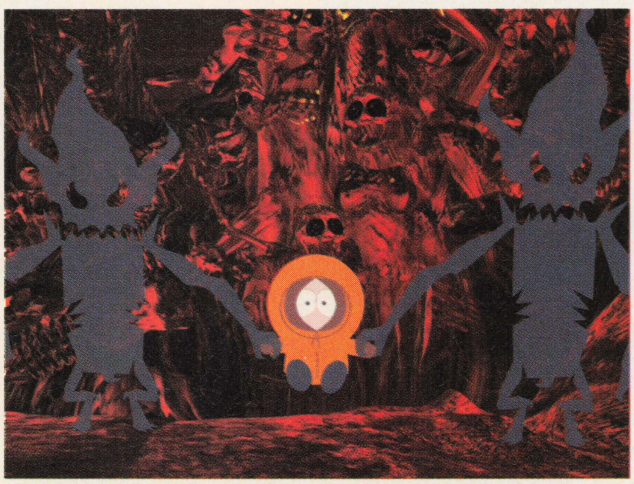
etary atmospheric software called Dust Devil, (available free on the studio's Web site). To animate Kenny's fall from grace, the group had to first convert the PowerAnimator-formatted character into Discreet's (Montreal) 3D Studio Max—which was used for the modeling, animation, and rendering—running on Intergraph (Huntsville, AL) workstations. Then, Steve Blackmon, Blur's lead effects animator, rewrote a customized in-house plug-in for Max to achieve the "hellacious" fiery atmospheric effects. With some additional tweaks, he was able to produce the desired silver cloud lining and billowy cloud-like look for the heavenly sequence.

"For the hell scenes, the [director] wanted the sequence to be very un-*South Park*-like," says David Stinnett, Blur's CG supervisor. "He wanted the imagery to be extremely rich and the fire as realistic as possible, as opposed to cartoon quality."

According to Blackmon, creating and animating the fire beasts that appear in this underworld proved especially challenging "because I didn't quite know what a fire beast should look like. I spent almost the first week sitting in front of my workstation, with my head buried in my hands, thinking, 'How am I going to do this?'" Once the fire creatures were conceptualized, the next hurdle was creating them. Blackmon's solution was to animate an underlying skeleton created in Max that did not render (was invisible), then stick atmospheric effects (fire) onto the creatures. The group also created fire particles using Digimation's (St. Rose, LA) Particle Studio that would trail off as the characters lumbered about, even though they always retained a solid core of fire. "We had several commercial atmospheric plug-ins, but they didn't have the control we needed to make the particles behave like actual fire, with fragments, blowouts from the hot core, and color fading," he explains.

To create the fiery background environment of hell, the team used some of Cebas Computer's (Eppelheim, Germany) ProOptic-Suite plug-ins, which provided a highly controllable gradient texture for the walls of flames surrounding the characters. While these underworld backgrounds were not as complicated as the beasts, they involved an enormous amount of layering so they would appear thick and vast, as requested by South Park Productions. "But when you keep stacking fire on top of fire, it looks like one big wall of fire; it doesn't get spacious," Blackmon explains. To rectify the situation, the group added more than 20 layers of smoke and debris, along with the fire. "It was a monumental amount of work adjusting each layer so every shot looked unique," he adds.

To composite the fire elements, including the beasts, the group used Eyeon Software's (Toronto) Digital Fusion, as well as some plug-ins for the package from 5D (Surrey, England), especially its Glass filter, to blend the particles and "give it that stringy look," says Stinnett. He notes that each fire beast required multiple passes within Digital Fusion because they were rendered as multiple elements, but then had to be re-composited with the other scene elements. "These are probably the largest composites that we have ever done here in-house."



To create and animate the fire beasts, artists at Blur used Max and, for the trailing particles, Particle Studio.

While producing some unique fire plug-in software for 3D Studio Max was challenging, perhaps the most exciting aspect for the animators at Blur was the fact that they got to play a role in Kenny's afterlife. "We're all big *South Park* fans from way back when the series originated," Blackmon says. Surely for them, as well as for the audience, their vision of hell will never be the same again.

Karen Moltenbrey is an associate editor of Computer Graphics World.

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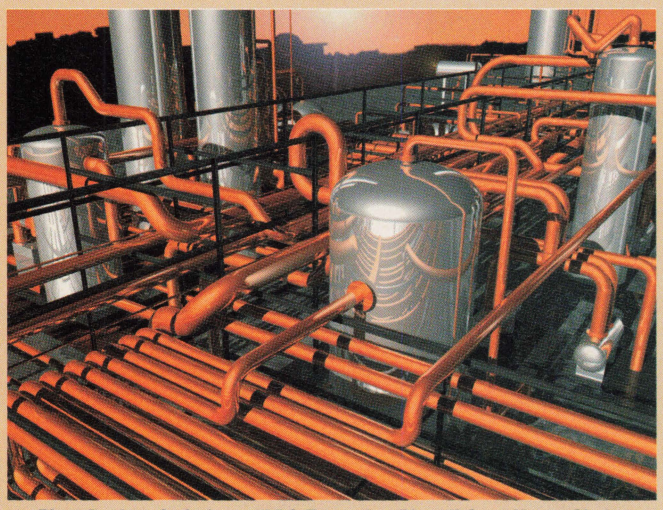
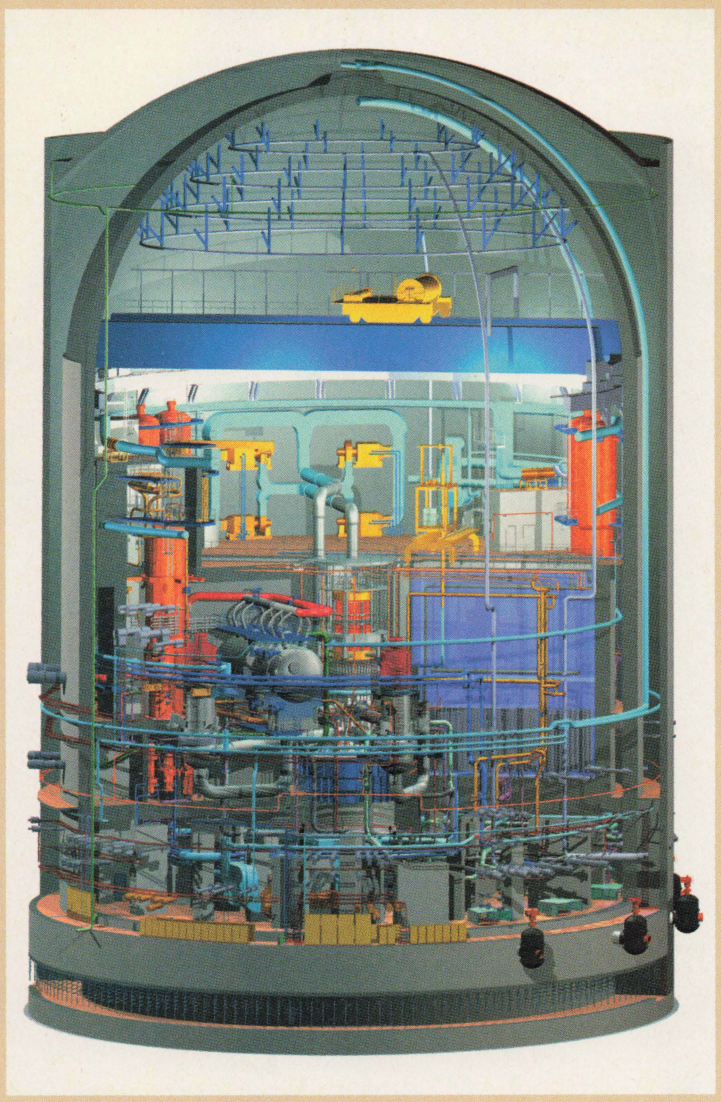
Best of Show: "Lecture Theatre," Tosh Townsend



Plant Design, 2nd place: "LPG Extraction Plant," Seon Yeong Choi



Plant Design, 1st place: "1000 MW Reactor," Elias Mayer

1999 Golden Mouse Awards

Intergraph Corp. (Huntsville, AL) recently announced the winners of its 1999 Golden Mouse Awards, presented to artists in recognition of their innovative computer graphics work completed during the normal course of business using Intergraph products. The annual competition showcases the top artwork from various categories based on overall design and technique as well as on technical and creative use of Intergraph software and system capabilities.

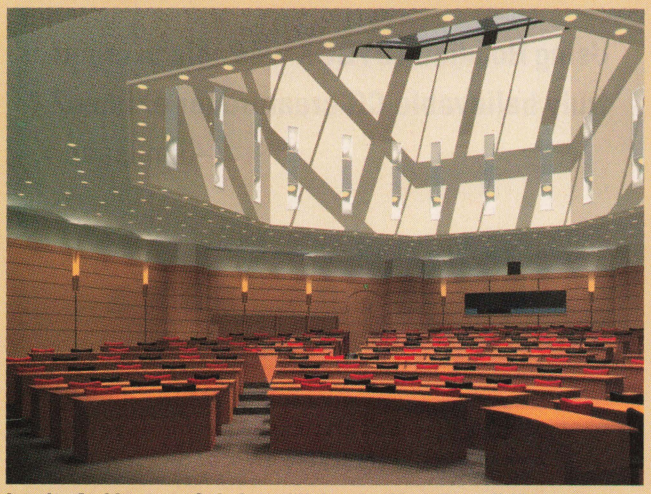
Selected as Best of Show in this year's 15th annual contest was "Lecture Theatre" by Tosh Townsend, director of UK-based TMB International, which was chosen from more than 150 total entries. Other honors were awarded in the following categories: animation, architectural exterior, architectural interior, civil engineering, graphic arts, mapping, and plant design.

This year's images, according to Intergraph, not only took advantage of the mature rendering capabilities of ModelView and the company's other visualization tools, but also reflected the users' breadth of imagination and expertise. The most distinctive characteristic of this year's winning images was the increased use of dramatic lighting effects and bold colors that, when combined, create an impression of depth and realism. Also prevalent this year was the expanded use of detail—in some cases physically modeled and in others generated during the rendering process.

A selection of the winning artwork appears on the following pages. —*Karen Moltenbrey*

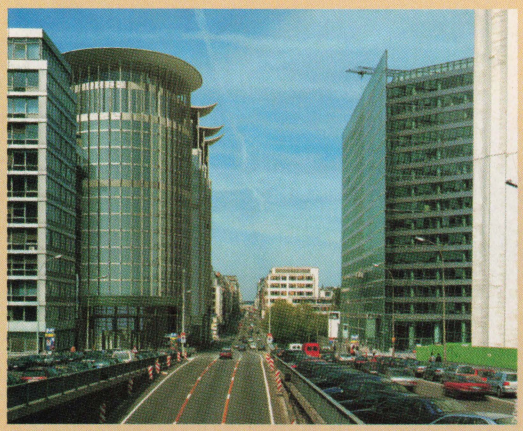
Exterior Architecture, 1st place: "The Ferrari of the Crimson," Masaru Takagi and Akira Ikegami

Interior Architecture, 1st place: "Chapel," Yasuo Hayakawa



Interior Architecture, 3rd place: "University Class Room," Hidesumi Hashimoto and Yujiu Nagai

Interior Architecture, 2nd place: "Atrium at Night," Sonoko Hayashi



Exterior Architecture, 2nd place: "Real of Virtual," Michel Penneman

Exterior Architecture, 3rd place: "A Home in the Caymans," Patrick McMillan

"It's a 12 second shot. The CG creature has to match this puppet and hit these positions. Let's have him skitter like a cockroach."

JIM ISAAC:
Special Effects Supervisor, eXistenZ, a master puppeteer with a keen eye for detail.

June 11.

First pass Aug-17: "Skittering doesn't really work, let's have him move more like a spider."

Pass two Sept-16: "That's better, now can we have the tendons in his neck strain more."

Over the next 2 months: "Great, but I'd like to see his back muscles rippling after his tail hits the ground, and let's make his skin ripple and stretch in his legs and...

3 weeks before deadline: "The secondary animation looks great, but I think we need to change his path up the gas pump...

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SIMULATION

THE SECRET LIFE OF VIRTUAL PLANTS

With botanical software, developers 'grow' public support for a botanical park by modeling a realistic landscape

BY KATHERINE TYRKA

In less than one year, L'Isthme des Sablettes, a short stretch of land on the southern coast of France, was magically transformed from a moderately desolate site into an urban seaside park sporting beautiful beaches and a large botanical garden. But before the actual landscape evolution took place, the entire area—including the 35,000 plants in the park—was modeled in 3D to successfully convince a skeptical community that the plan would really work.

While the southern coast of France has long been a popular resort area, sprawling apartment complexes and retail establishments erected in the 1970s contributed to overdevelopment of the region during a period of general disregard for the impact of commercial projects on the overall landscape. The results of that building boom created a more wary public, whose backlash now often means that any proposed new development—good or bad—can be delayed for many years, as community associations battle with the regional government on the viability and impact of any change.

In a climate such as this, landscape architect Alain Faragou must not only conceive and implement redevelopment projects, but also effectively communicate his vision to the general public. That is no easy task, since his project proposals are, by definition, "living" projects that change over time. To do so, his Nice, France, landscape architectural firm—the Faragou Agency—uses Autodesk's (San Rafael, CA) AutoCAD R14 design software to produce the schema used by the engineers and construction companies as well as for the presentations to the administrative councils. However, for L'Isthme des Sablettes, the company went much further, using 3D modeling to show what the proposed park area would look like in the year 2025, when the park reached full maturity.

Mature palms cast shadows on a sidewalk while light from the sea shines through foliage on the left in a landscape presentation designed to help win approval for a development project along the southern coast of France.

"L'Isthme des Sablettes was a project that needed a better level of communication for two reasons," says Faragou. "First, the administrative council was made up of a broad, demanding group of administrators—including the mayor and regional representatives, as well as representatives from the European Community, since they contributed to the funding of the project. Second, the previous development plan for L'Isthme des Sablettes was so inappropriate for the region that it was abandoned mid-project due to

Before and after: The top image shows the current state of L'Isthme des Sablettes in the south of France, while the bottom image shows how a proposed park on the land would appear in 25 years after plants added during landscaping reached maturity.

All images courtesy of JMG Graphics.

The appearance of trees along a walkway in years to come is enabled through the Genesis program, which, using dynamic botanical parameters, can realistically simulate growth at any stage of a plant's life.

public outcry. In these circumstances, it was crucial to our success to provide the best visualization possible."

Two graphic designers spent about a month modeling and preparing the 3D images for presentation to the council. Following the council's approval of the project, numerous public expositions took place to win public support.

First, the designers used the 2D AutoCAD data for the general layout of all the objects (buildings as well as bushes and plants). Next, they modeled all the architectural images in Discreet's (Montreal) 3D Studio VIZ (a former Kinetix product) and all the plants in Genesis, an application distributed by JMG Graphics (Gentilly, France) running Windows NT 4.0 and Unix on SGI (Mountain View, CA) Indy workstations. For the plant renderings, the artists used the Landmaker module from JMG Graphics' Orchestra application. Last, the artists had to show the park within context (in the background of the site), which was accomplished by compositing the images from 3D Studio VIZ, Orchestra, and a background photo in Adobe Systems' (San Jose, CA) Photoshop.

"Orchestra's ability to handle the billions of polygons that can be involved in the modeling of plants was key to this project," explains Guillaume Caron, one of the designers. "We have since imported the buildings from 3D Studio VIZ into Orchestra, with a total of approximately 550 million polygons for the entire park."

Planting an Idea

Orchestra and Genesis were developed following extensive research during the last 20 years by CIRAD, a government research center in Montpellier, France. This effort led to the establishment of botanical laws, which formed the base of Genesis. The application is capable of taking any plant, at any age and season, and simulating it in 3D with an amazing realism, including texture mapping from scans of the plants themselves. The plants can then be exported in a variety of formats, including OBJ, 3DS, DXF, and BMP. The program also can be used as a plug-in to Alias|Wavefront's (Toronto) Maya.

"We modeled the 300 different types of vegetation—with a total of 35,000 individual plants—in Genesis," explains Faragou. "As a landscaper, I am particularly demanding when it comes to plants. This is not only because landscape architects use plants as our 'vocabulary,' but also because we design for all perspectives—close enough to touch a plant or far enough away so you can see the plants as a mass." In essence, the Orchestra visualization mirrors the human perspective so that "we can even give a view of the landscape when there is more humidity in the air, which modifies the plants' colors," he adds.

Genesis provides access to a database of virtual seeds, each containing an associated document that supplies the dynamic parameters of its growth. This means that while each plant will grow according to the natural laws of the plant type, no single plant is identical to another. "This becomes particularly important to the realism of the simulation, since a series of identical plants would immediately strike the eye as artificial," explains Stephane Gourgout, director of JMG Graphics.

Once a plant has been "grown", it can be viewed as a polygonal model, a mesh, or a simulated, texture-mapped image. Virtual pruning (with the resulting characteristic growth after trimming) is also possible. Users can position the vegetation into the terrain with the mouse, or use the software tools to "plant" large zones, either in rows or in naturally scattered forms.

"The ability to transfer a project into 3D means that we can see the complete volume of the landscape and verify its equilibrium from all different points of view to better see any problems in the plan," says Faragou. "The additional aspect of the fourth dimension—time—allows a landscaper to 'live' with the project and to better understand its evolution over time."

This application is particularly imperative today, Faragou notes, to inform the public, which needs to be reassured that the irreversible errors in regional development that have been made in the past will cease, and that any proposed development project will harmonize with the area, rather than destroy it. "Images taken from these applications have become crucial to our agency in order to convey this information," he adds.

This need to communicate effectively with the public has also resulted in the recent passage of laws in France that require developers to submit accurate images of what the completed project will look like, both up close and from a distance. According to Faragou, this requirement is an opportunity to expand the use of the botanical programs to visualize not only his company's own projects, but also those by other landscape architects, urban planners, and government agencies.

In view of this first visualization's success and the public's appreciation of these images at the expositions, the Faragou Agency should have no difficulty planting for the future.

Katherine Tyrka is a freelance writer based at the GEID Press Agency in Paris. She can be reached at ktyrka@compuserve.com.

Key Tools **Genesis and Orchestra**, JMG Graphics (www.jmg-graphics.com) infoNOW 51

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BROADCAST

TURNED TO STONE

Animators piece together a commercial featuring ceramic-tile characters that come to life inside a mosaic

BY KAREN MOLTENBREY

© 1999 Mannington Floors. All images courtesy of Blue Sky Studios.

To achieve the look of an actual mosaic, the animators had to lay, then manipulate, hundreds of CG tiles by hand, as stone mosaic artists have done for thousands of years.

Blue Sky Studios has added a new dimension to the centuries-old art form of constructing a mosaic, and in doing so, has brought 2D tiled characters from a print campaign to 3D action in a 30-second broadcast commercial for Mannington Floors.

"Mosaics" features four ancient Roman characters in a tile mosaic who come alive under the not-so-watchful eye of a museum security guard. A toga-clad woman in the mosaic is so impressed with the ceramic-like appearance of the vinyl flooring that she is compelled to bend down and reach out of the artwork's frame to touch it.

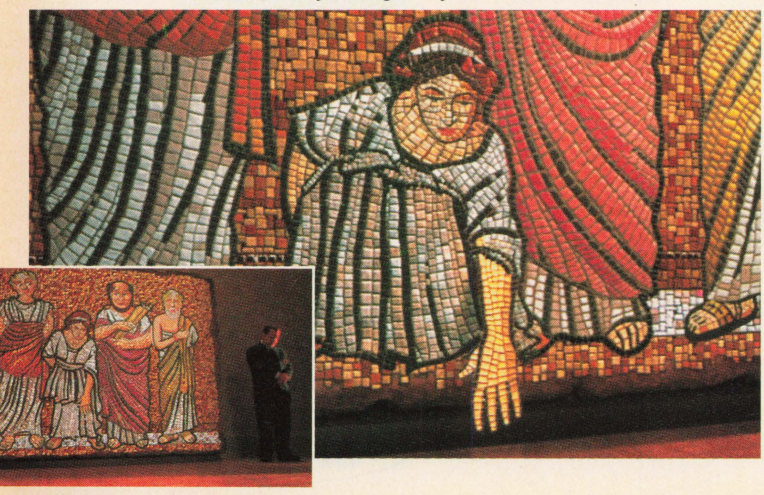
On the surface, the commercial seems simple. But, in reality, Blue Sky (Harrison, NY) had to figure out a way to move computer-generated characters—made from hundreds of 3D tiles—on a 2D plane in a way that would simulate 3D motion. This required the studio—known for its leading-edge 3D CGI work, including its Oscar-winning animated short film *Bunny*—to adopt a 2D mind-set.

"It's a unique concept: how to represent 3D information in 2D," says Jan Carlee, animation director. While 2D cel animation does this every day, the issue presented with this project centered on the 3D tiles and the 3D information they created. "We couldn't squash and stretch the tiles to fit the animation because that would distort the message we were relaying to the audience, that these are ceramic tiles, not pieces of rubber."

The solution was to create an elaborate computer layering of the tiles so that as the surface tiles moved, a new layer of tiles underneath would subtly slip into place. "It's similar to an escalator," Carlee explains. "Levels of tiles are on top of one another, but they can slide out from underneath, exposing a little bit of the tile below." This created the illusion of 3D perspective while the characters looked as if they were on a flat surface.

To add to the challenge, the group had only seven weeks to figure out the methodology and complete the spot.

In the commercial "Mosaics," Blue Sky brought to life 2D characters by affixing layers of tiles onto a 3D form and subtly inserting new layers as the characters moved.



Once a solution was found, the group scanned a 2D illustration from the original print campaign to use as a guideline for placing the 3D tiles. Because the artist "faked" 3D in the illustration, some of the highlights, shading, and lighting did not look realistic when modeled in actual 3D. "We made each tile in Maya the color it was supposed to be in the final rendered scene, then exported that information to our CGI Studio software. At that point, it looked more like flat-color art than a three-dimensional mosaic made of antique tiles," explains modeler Alex Levenson.

So the Blue Sky artists, using Adobe Systems' (San Jose, CA) Photoshop, repainted and redrew some of the characters' faces so the illustration could be followed as a color map for the project—a process that was extremely time-consuming.

To get a feel for the pacing of the characters' movements, the Blue Sky group shot video footage of costumed actors performing the movements live. Then, artists with strong 2D experience sketched each character and hand-animated the piece frame by frame to create a template for the computer animation. This showed how the tiles would shuffle around to simulate the movement. "The most difficult part was to work out that movement; it's a real sleight-of-hand trick," Carlee says. "All the 3D animators on the project were also 2D animators; I wanted people who understood how to represent something 3D, in 2D."

To create the characters, the team built four base objects in the shape of the four subjects using Alias|Wavefront's (Toronto) Maya and Alias running on SGI (Mountain View, CA) workstations. They used the same tools to build the individual 3D tile pieces, each with its own geometry. Every tile piece was then assigned color, texture,

and material attributes using Blue Sky's proprietary CGI Studio texturing software. Studio was also used for rendering, while the company's proprietary Compose software was used for compositing.

Using Maya, the group animated the base shapes, which served as the grout between all the tiles, and hand-laid the tiles on top of the base "one tile at a time, to match the artwork," Levenson says. Up to eight tile layers were added to the base along the Z axis to achieve the motion.

If the characters just moved around on a 2D plane, the tiles could have been hinged. But the woman turns from a side profile to a head-on view, and even reaches outside the 2D plane. "So you have to relay 3D information of someone turning her head, but it needs to be reduced to 2D, to the plane of tiles," explains Carlee. When this movement occurs, the surface space of the character changes, so the number of tiles on that surface must change.

"Since we didn't want new tiles just popping into place from nowhere, we had to find a way to fill that space without being too obvious, meaning new tiles had to be introduced and other tiles had to somehow disappear," says Carlee. "Think of it like a deck of cards, where there are levels of tiles stacked under one another. When more surface space is needed, the tiles are smeared, or spread out, so you can see a little part of each tile below the 'deck'."

A Sticky Situation

Once the tiling was laid, the group had to ensure that the hundreds of sliding tiles would stick to the base objects, no matter how much they deformed during animation. This required Blue Sky to write code that would enable it to achieve this goal—at least to an extent. "It's a real art form to develop a mosaic. To maintain the integrity of the piece, we had to manipulate the tiles by hand," Levenson says.

While the code prevented the tiles from moving too far, "the animators had to do a lot of work to keep those tiles looking coherent, especially when the woman's profile changed," Levenson says. "When the modelers animated the base shape, we would see what happened to all the tiles we laid at the start position and then tweak them to ensure they were in the correct position at the end [of the movement]."

The group was careful not to change the tile shapes too much as they animated, Levenson says, "because that would have been a dead giveaway that this was computer generated." In fact, the modelers used pictures of old, authentic mosaics as reference for its CG effort.

"We wanted an automated way to position the tiles artistically, but we ultimately did it just as they did thousands of years ago—one tile at a time," explains Levenson. While the computer enabled the artists to copy similar rows, they still had to hand-tweak the pattern to mask repetitiveness. "Basically, we built this like a traditional mosaic, only it was done in CG."

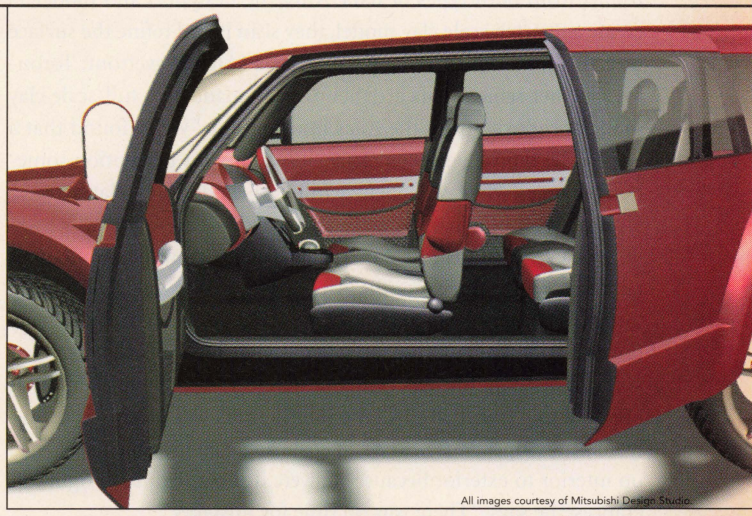
Key Tool **Maya**, Alias|Wavefront (www.aw.sgi.com) **infoNOW 52**

CAD/INDUSTRIAL DESIGN

ONE FOR THE ROAD

Computer-aided industrial design helps Mitsubishi turn a concept into reality

BY KAREN MOLTENBREY



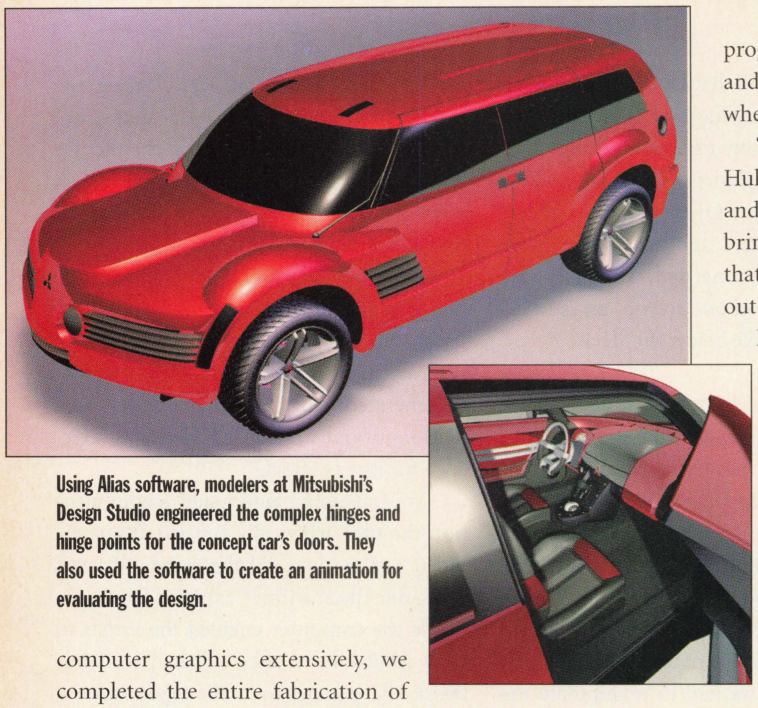
All images courtesy of Mitsubishi Design Studio.

Using industrial design tools, modelers at Mitsubishi's Design Studio engineered a fully functioning concept sports-utility vehicle in just a few months.

When the designers at Mitsubishi Motors wanted to make a splash at the North American International Auto Show, time was not on their side. Because the team had only a few months to produce a working model, the members had to become just as creative with the development process as with the design of the vehicle. As a result, the group turned its engineering and design process inside out—or rather, outside in—by first creating an eye-catching exterior design, then engineering it with computer-aided industrial design tools.

Mitsubishi's R&D Design Studio in Cypress, California, was the driving force that developed the company's concept Super Sports Utility (SSU), a combination sports car/sports utility vehicle. Not only were the designers responsible for originating the idea and creating a stylized look, they also engineered the concept into a fully functioning vehicle.

According to chief designer Dan Sims, most concept vehicles primarily serve as a styling indicator for a car company, and as a result, most of the vehicle's parts do not function. "We wanted to indicate and forecast a styling direction, but we also wanted to create a vehicle that we could try out by driving it," he says. However, the development team only had a few months to evolve its idea from paper sketches into a finished, drivable product. "By using



Using Alias software, modelers at Mitsubishi's Design Studio engineered the complex hinges and hinge points for the concept car's doors. They also used the software to create an animation for evaluating the design.

computer graphics extensively, we completed the entire fabrication of this vehicle in four months, and in the auto industry, that time frame is completely unheard of."

To achieve this ambitious goal, the team had to alter its usual workflow structure. Normally, the group refines its design by working sequentially with a clay and CG model to achieve the best results from both types of data. After the designers and modelers create a quarter-scale clay model, they scan it and refine the surface on a full-scale digital version using Alias (Alias|Wavefront; Toronto). Further refinements are then usually made on a full-scale clay model, produced from the Alias information. "We've found that a CG model typically gets us really close, but your perception somehow changes when you view a full-size model on a flat screen," Sims maintains. "That's why we alternated back and forth."

However, that process is extremely time-consuming, sometimes taking as long as three months just to produce clay models. To speed things up, the group used both types of data in tandem. By keeping the computer data up to date, says designer Jon Hull, the team was able to develop the exterior and interior data concurrently, as opposed to sequentially. "All the interior data was produced entirely on the computer, so we had to ensure that all the final parts lined up interior to exterior because we were dealing with such tight tolerances," he says. "There was no time for mistakes."

Once the exterior design was basically complete, in-house modelers began making molds and casting parts directly from the full-size clay model. Meanwhile, another group of designers and modelers chose to get less physical with the engineering aspect of the vehicle by using the exterior surface data in Alias to engineer the vehicle.

Although the SSU was a concept vehicle, its engineering design was based on an actual car—a Mitsubishi Gallant station wagon from the Japanese market. "It was already all-wheel drive and had the hardware we needed on a station-wagon body," Sims says. This enabled the designers to import much of the production vehicle's engineering data (such as the fire wall, suspension, and interior-stamping) using its proprietary Merit software, a Catia-based CAD program. The data was then translated into standard IGES data and read into Alias running on SGI (Mountain View, CA) Octanes, where all the modeling and surfacing was done.

"The level of accuracy you can get using Alias is amazing," says Hull. "A lot of people don't think of Alias as engineering software—and technically, it isn't. But we were able to use it to accurately bring in engineering data and engineering hard points [restrictions that cannot be changed], then engineer hinges and so forth without changing programs."

For better showing a show car's interior, Hull explains, engineers typically outfit the vehicle with "suicide doors," where the front door opens in the usual manner (right to left) but the rear door opens in the opposite way (left to right). However, this creates a situation where the rear door cannot be opened without first opening the front door because there is a slight overlap. "This was unacceptable to us, so we created a complex-shaped hinge and hinge points using Alias," says Hull.

To ensure that there would not be any interference between the door and the interior door panel, the designers verified its fit by creating an animation file in Alias, since there was little time for testing it on a clay model. "That's where we first used animation on this project," Hull says. "This enabled us to determine how far we could open the doors before they started to dig into the body, so we knew where to place the hinge stop." The group also used Alias to produce a two-minute VR-type of animation that was played during the auto show that highlighted many of the vehicle's features.

Production-Ready

"The most impressive part of the project was how close the show car was to a real production car. Most show cars are just that—for show—and cannot be driven," Hull says. "You'd never see the level of detail that we put into our doors, with all the shut surfaces [eliminating air gaps]. Ours was a fully functioning vehicle that we tested on the streets of Irvine [California]."

Another distinguishing feature of the SSU was the fact that it was fabricated almost entirely in-house, instead of by a company specializing in the construction of concept vehicles. "When we received the go-ahead to build the SSU, we never considered allowing it to be built by an outside firm," says Roger Zrimec, Design Studio director. "That would be like parents sending out a baby to be raised by someone else, with the hope that it grows up to be exactly as they planned." Instead, most of the parts were created and then assembled in-house, although a few items were outsourced to Scicon (Valencia, CA) for rapid prototyping and to CTEK (Santa Ana, CA) for milling the actual parts.

"For us, the vehicle was more than a styling model; it was a test bed for new technologies and our working processes," Sims says. "We didn't have time to go back and forth between a digital and clay model for the interior, so we just went right in and engineered it on screen." While a physical model is still needed for certain verification, he adds, this project proved that the design team can go much further using digital tools than it ever thought possible—or ever dared to try.

Key Tool **Alias**, Alias|Wavefront (www.aw.sgi.com) infoNOW 53

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COMPUTER GRAPHICS WORLD

INNOVATION IN VISUAL COMPUTING

formZ 3.0

Difficult to pigeonhole, hard to beat

BY JEFFREY ROWE

Image created by Scott Simmons, Live Wire Productions, Los Angeles © Live Wire Productions

FormZ is a versatile design package used in a wide range of professions—from architecture to game development.

Autodessys' formZ 3.0 is difficult to classify, primarily because it does things differently from most other 3D modeling packages. Basically, it's a NURBS-based hybrid solid/surface modeler with a proprietary modeling kernel/engine.

One unique aspect of formZ is its wide range of users. It got its start in the architectural and industrial design worlds, where it still enjoys popularity as a visualization tool.

Image created by David Rindner, Columbus, OH.

For constructing objects, you can draw across windows and snap to different types of entities simultaneously.

But formZ also has a home in entertainment production, making its competitors not only traditional solid and surface modelers, but products such as 3D Studio Max as well.

The new version features several enhancements. Most significant are the ability to create objects with multiple parametric "personalities," an overhauled interface, new ways to create splines, animation capabilities, and enhanced drafting.

The ability to handle multiple personalities is unique to formZ. Version 3.0 can merge different object types so that NURBS, Bezier curves, Coons patches, analytic primitives, polygonal objects, and metaballs can be separate representations or can coexist on the same object. Each object can have a distinct personality and behavior.

FormZ is not for casual users. For starters, its default interface is an eyeful. Though the interface is customizable, autodessys devoted too much screen real estate to tools and palettes at the expense of the "action" area. After you get over the initial learning hump, you can model and manipulate some unique forms relatively quickly and easily. It's easy to manipulate primitive object parameters (for example, converting a revolved sphere to a geodesic sphere). In addition, derivative objects, such as sweeps and revolutions, are parametric. Unfortunately, formZ does not have advanced parametric or feature-based objects, such as constraints.

Version 3.0 offers modeling and animation features not found in other packages in the $1500 price range. NURBS and parametric primitives give formZ 3.0 some of its 3D design flexibility. You combine NURBS and primitives with polygons, patches, meshes, skinning, sweeps, and other tools for modeling organic forms.

In addition to previously available controlled meshes for creating hybrid NURBS and polygonal objects, 3.0 features new pure NURBS structures, called nurbz, that you can create from control lines by converting analytic primitives or from objects of revolution, sweeps, and skins.

Animation is now integrated into formZ 3.0 so that you can create walk-throughs and fly-by animations. You can define cameras and use them to produce animations and create animation paths from keyframes, which you can edit either interactively or numerically.

Autodessys also improved drafting in formZ with a major rework of its 2D and 3D tool sets. It revised the internal data structures, introduced the use of special display lists, and revised buffering and interactive drawing techniques. Plus, it improved the dimensioning interface to reduce the complexity and levels of dialogs. You can now place dimensions as associative or non-associative entities and easily reposition them.

For data import/export, all file formats—for both object and image data—are restructured to share common options and to interface consistently and uniformly, to the extent required by each format. The practical gain of this is uniformly predictable behavior when a variety of formats are used.

FormZ is a unique product in terms of its multifunctionality and price. Although it's geared more for designers who are comfortable with CAD concepts rather than casual users, it is versatile enough that it should find a welcome place in professions ranging from architecture to game development to industrial design. formZ is a tough application to classify, but the product has no competition in its particular market space.

formZ 3.0

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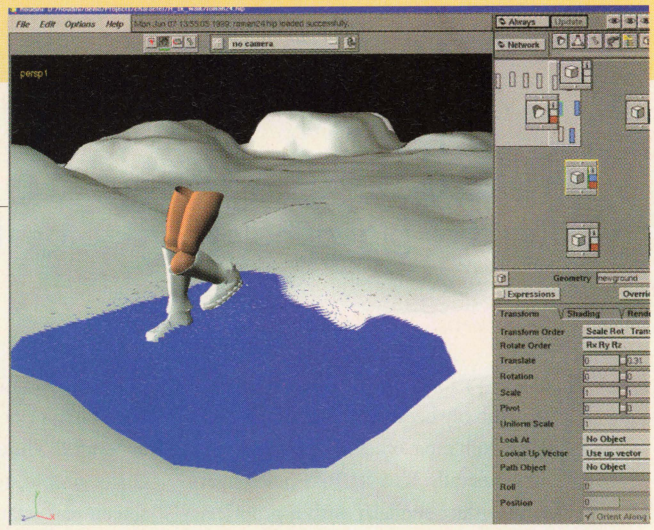
Jeffrey Rowe is the principal of Cairowest Digital Syndicate. He can be reached at jrowe@cairowest.com.

Houdini 3.0

New technologies enhance the complete film-effects package

BY SANFORD KENNEDY



Houdini's particle systems allow moving feet to splash into a pond and send up spray emitted by the line of intersection between the feet and the water surface.

Few 3D animation programs today provide every tool and feature that professional digital-effects creators in the film industry require. Houdini 3.0 from Side Effects Software is one of the few that does. From the creation of photorealistic character animation and massive particle flames to 10-story-tall dinosaurs and meticulous compositing effects, Houdini's modular procedural programming system delivers control over every aspect of animation, down to the dynamics of an individual particle.

The new version boasts improvements in nearly every area. A major enhancement is the ability to interact with the program during real-time playback for puppeteering or performance-animation applications.

Houdini 3.0 also incorporates three powerful new modeling technologies, including higher-order rational curve networks, procedural radial fillets, and an enhanced version of Pixar's subdivision surfaces, which quickly and easily enable modelers to add high levels of localized detail to their polygonal models.

Side Effects cofounders Kim Davidson and Greg Hermanovic have worked hard to make Houdini 3.0 the first choice for software around which to build a production studio. The program comes with extensive data I/O capabilities, and accepts MIDI, motion-capture, and motion-control camera data, as well as animation and audio files, plus model files from other software in the production pipeline. A new IGES import capability creates access to software such as Rhino 1.0 and CAD programs, with which you can create NURBS models for Houdini.

Using Houdini reminds me of designing flow charts or ladder programs. The interface is divided into modules designated by acronyms such as SOPS for surface operations, POPS for particle systems, CHOPS for channel operations, and COPS for compositing operations. The workflow is organized in the program's Visual Procedural Network. The network employs Object Tiles and Operator Tiles, which represent object components such as geometry or operations such as NURBS skinning or particle generation.

After you arrange the tiles in a meaningful sequence, you connect them to one another by feeding the output of one or more tiles into the input of the subsequent tiles. Each tile type has its own associated parameters and data-entry menus that control everything from how the object is to be displayed to how a particular operation should modify the data.

The workflow and the multiple interconnections can become complex when you are creating a scene. But because each operation is clearly defined, the workflow eventually takes on a meaningful structure.

Worthy of note is Houdini's Hierarchical Surface technology, which lets you paste a high-resolution NURBS component onto a lower-resolution NURBS surface, such as when attaching a nose or ears to a basic head model. You can also use it to assemble a face from different pasted components, then wrap a pretextured, smooth grid around the entire assembly to obtain a texture-mapped seamless face.

Particle systems have for some time been Side Effects' area of strength. Houdini's are without equal, giving you particle paths, dynamics, flocking, atmosphere, numerous types of particle emitters, animated particle flames, rain, impact detection, spawning, and spray from the impact of objects with the surface of a water object.

A major factor in Houdini's effectiveness as a pipeline for studio production is its built-in RenderMan interface. Houdini's Mantra renderer can pass its materials to its internal RenderMan interface to create shaders that enable you to preview a scene as RenderMan would render it. However, the generated shaders work internally only, and are not passed on to the final .RIB file output. Good news for Unix-based studios is the upcoming port of Houdini to Linux, a version of Unix that runs on inexpensive PCs.

Houdini 3.0 also now features WREN, a software-based solution for advanced hidden-line wireframe rendering with silhouette edge detection. Developed by Side Effects for a client that produces the Japanese style of animation known as anime, WREN enables users to render wireframe models with precise control over interior lines.

In the final analysis, Houdini is a challenging package to learn. But it's the top 3D animation system available for producing high-quality visual effects for film.

Houdini 3.0

PRICE: $21,000 (includes a year of support and upgrades)

MINIMUM SYSTEM REQUIREMENTS:
IRIX: SGI running IRIX 6.2 or better
NT: Alpha processor or Intel Pentium Pro/II/III processor; Windows NT 4.0; 64MB of RAM

Side Effects Software
Toronto
416-504-9876
www.sidefx.com

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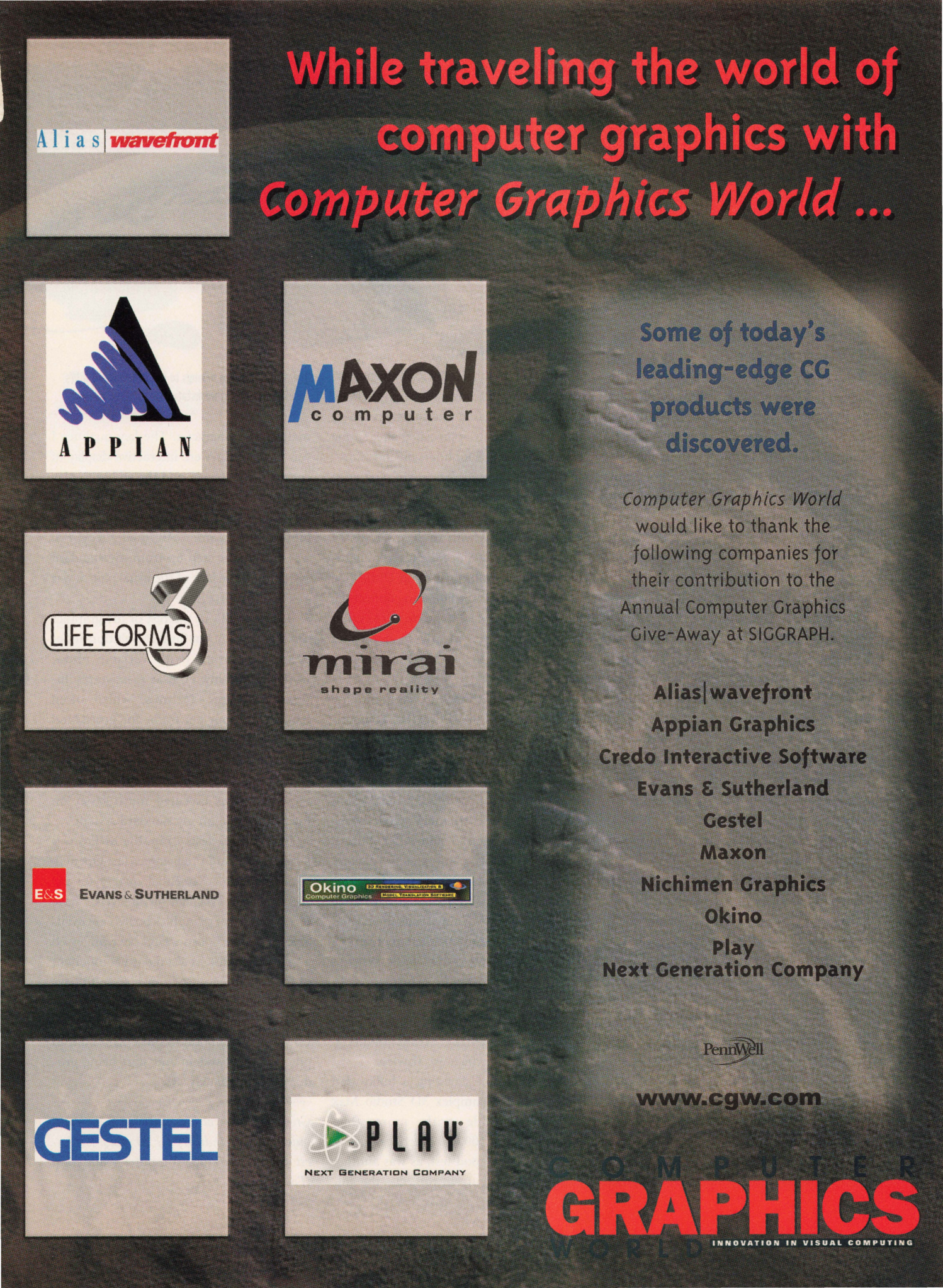
Sanford Kennedy has been an animator, author, and special effects designer in the motion picture industry for 20 years and owns an animation studio in Los Angeles. His Web site is www.sanfordkennedy.com.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IntelliStation M Pro

IBM beefs up the mid-range

BY GREGORY MACNICOL

The NT-based M Pro belongs to the mid-range of IBM's IntelliStation line of workstations.

The IBM IntelliStation M Pro is aimed squarely at mid-range users, professional 2D and 3D CAD designers, and digital content creators who demand strong performance but are also cost-conscious. With this audience in mind, IBM has packaged a reasonably priced ($4100) system with all the essential components that, compared with IBM's much more expensive Z Pro and the more affordable E Pro, is the best compromise for effective productivity.

The unit I reviewed was a 550MHz Pentium III-based system (dual processors are an option) with 256MB of RAM (expandable to 1GB), a 512K Level 2 cache, and an UltraWide SCSI 8.6GB Cheetah hard disk. Microsoft Windows NT 4.0 came loaded on the system. Other hardware included a 40X CD-ROM drive, an onboard 16-bit Sound Blaster Pro-compatible audio subsystem, and a 10/100-Mbps Ethernet adapter.

The unit's tower case offers plenty of room for expansion, though there are only two available bays for adding devices such as a DAT or DVD drive. The motherboard provides two ISA and three of four PCI slots, which should be enough for the usual add-on boards.

The M Pro I tested used the AGP-based Diamond FireGL1 for its graphics display subsystem. The board has 32MB of video memory and can display a resolution of 1920x1200 pixels at 16.7 million colors. It supports a refresh rate up to a smooth 85Hz. The Fire GL1's geometry pipeline polygon setup engine supports multithreading, meaning it can take advantage of the optional dual-processor mode, thus providing excellent interactive performance. As one would expect, the board supports OpenGL, Direct3D, and Heidi APIs.

A feature you don't find on spec sheets but that is especially important to me is how much noise a system generates. Luckily, the two fans in this unit are relatively quiet, which I really appreciated after sitting next to the machine for hours on end.

The M Pro provided excellent plug-and-play capability, as the network interfacing is automatic. Installation of my essential 2D and 3D programs with the fast CD-ROM drive was a breeze. Since the external hard-disk interface was limited to an UltraWide SCSI, I had to use an adapter to connect the machine to my older "standard" drives. But all in all, IBM has clearly made strides toward making the system immediately operational.

The real test of the M Pro was in running the graphics tools that I use. (For comparison, my everyday machine is a single-processor 450MHz Dell with a Matrox Millennium G200 graphics card.) My primary program is 3D Studio Max (Versions 2.5 and 3) from Discreet. Other essential tools include Adobe Systems' Photoshop 5 and After Effects, Spaceward's Satori paint system, Eyeon's Digital Fusion compositor, and DarkTree Textures generator from DarkSim. All these tools are well-known time-consumers, and running them represents a good test of a system's overall performance. In addition, loading them was a good test for the system's compatibility—which was flawless.

Loading a bulky and complex 3D Studio Max file with more than 100,000 vertices was a good test, as was another current project—the animation of a character. The key qualities I was looking for were interactive display of complex 3D objects; and the ability to play shaded animations in real time. Because I was doing character animation, these capabilities were essential. All in all, the M Pro was a dramatic step up from my standard system, and the lack of the usual pauses was a delightful surprise.

I then tried out the rest of my graphics tools. Satori, known for its resolution-independent painting (with variable undo) worked smoothly, even at massive resolutions. DarkTree Textures, which often requires an hour per frame for procedural texture generation, ran significantly faster, and Photoshop zipped right along, even when I used the most complex filters. All these programs executed much faster on the M Pro than on my standard system.

With all the tests I ran, the M Pro was flawless, fast, and predictable. The OpenGL performance—an essential quality for 3D creators—was excellent on all levels. I have few gripes. Faster graphics boards are available, of course. I also would have preferred a larger hard disk as a standard component of the system because I never seem to have enough space. However, for a mid-range system, the M Pro is cost-effective and would be a real boon to those who want to plug in a new system and start being productive immediately.

Gregory MacNicol has written for the computer graphics industry for 20 years. His latest book is Desktop Computer Animation *(Focal Press)*

IntelliStation M Pro

PRICE: $4139

CONFIGURATION AS REVIEWED:
550MHz Pentium III processor; 9.1GB hard drive; 256MB of RAM; Diamond FireGL1 graphics card; Microsoft Windows NT 4.0

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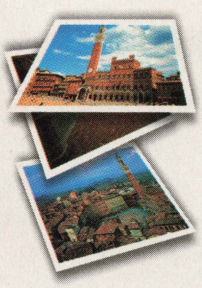

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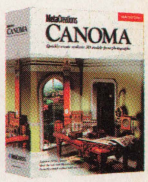

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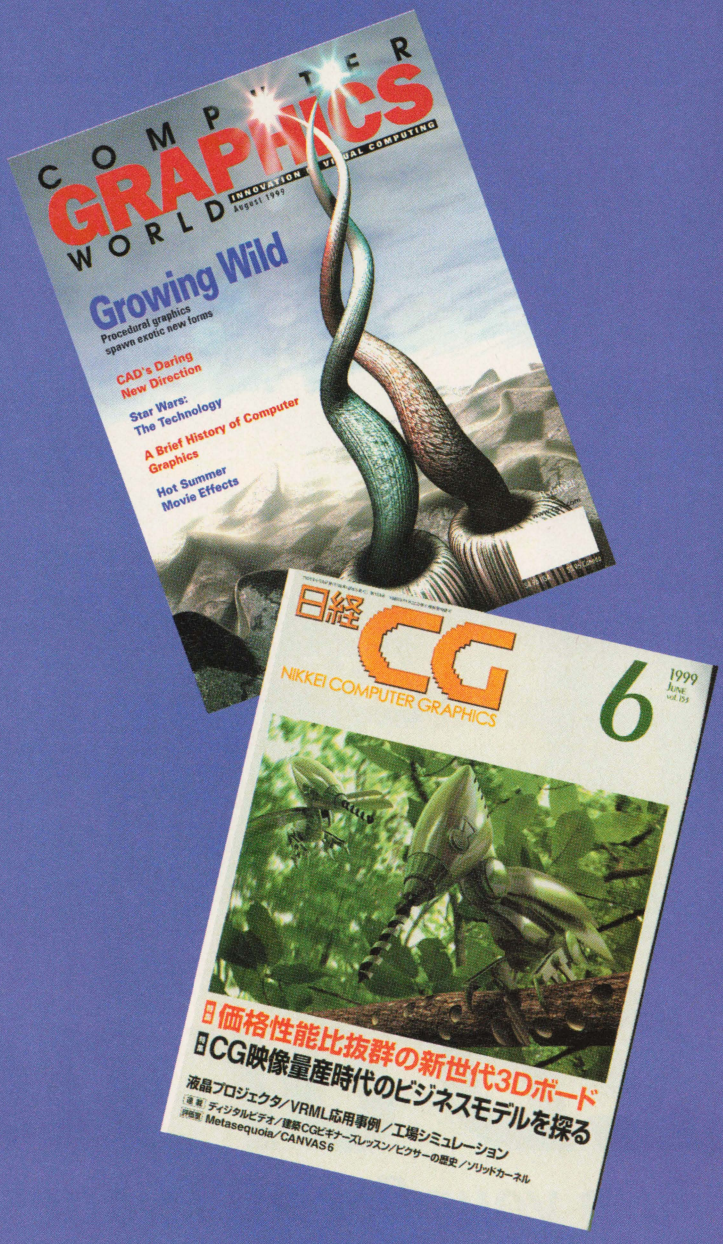

Nikkei Computer Graphics

SOFTWARE

ARCHITECTURAL ENGINEERING

MODELING

WIN Originally released for the SGI platform, 3Dipsos from MENSI is now offered on Windows NT. The software permits the consolidation of points of view and the coalescence of point-cloud data into either geometric constructs or surface-mesh models that can be exported to a variety of programs. The software requires at least a Pentium II class processor running at 366MHz with at least 128MB of RAM. (Norcross, GA; 770-613-5255; www.mensi.com)

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DESIGN ENGINEERING

VIEW AND MARK UP

UNIX Imagenation 5.1 for Unix from Spicer gives clients the same functionality that Windows users have to view, mark up, and edit documents. For example, CAD designers working in Unix environments can also participate in drawing revision control and approval processes with Windows users within an organization. Users can access more than 130 data types, including ADRA CADRA, AutoCAD DWG and DXF, Co/Create ME10, and HPGL. The price ranges from $495 to $1595. (Kitchener, ON; 519-748-2462; www.spicer.com)

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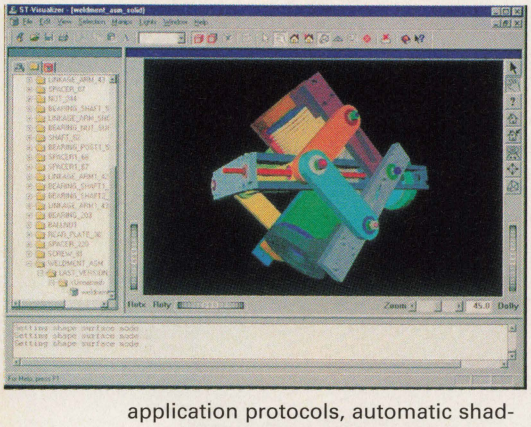
STEP VIEWER

WIN Version 3.0 of ST-Visualizer from STEP Tools is used to display wireframe and solid-model geometry in STEP part files. The product features support for assemblies and AP-214



application protocols, automatic shading of 3D components, across-the-board performance increases, and COM Interfaces for automation. With new automation capabilities, outside applications can interact with the program and have it perform tasks like loading a file or manipulating an object by changing the camera position. The product can communicate bidirectionally with an outside application and report whenever the user displays, hides, or changes the object selection within ST-Visualizer. (Troy, NY; 518-276-2848; www.steptools.com)

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3D VIEWER/EDITOR

WIN From Template Graphics Software comes 3Space Assistant 3.0, an interactive 3D viewer/editor that enables non-technical staff to import, view, manipulate, edit, and share 3D CAD, VRML, and Open Inventor files on the Internet and inside desktop applications. A new 3D-decimation module enables users to create levels of detail with fewer polygons prior to the rendering process. Users are offered five transparency modes rendered by OpenGL and embedded stereo viewing. Users can also create vectorized output using CGM, HPGL, or PostScript format. The price is $149. (San Diego, CA; 858-457-5359; www.tgs.com)

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LIBRARIES

SCI-FI TEXTURES

WIN/MAC Marlin Studios' Amazing Sci-Fi Textures product features more than 550MB of textures that can be used to create high-quality science fiction and space scenes. The textures can be tiled multiple times without showing seams in a graphics program. Many of the images are post-processed as alpha-channel maps with transparency and most textures have an accompanying bump-map. The textures and matching bump-maps come in four sizes: 1600x1200, 1024x1024, 512x512, and 256x256. The price is $149. (Arlington, TX; 817-860-0596; www.marlinstudios.com)

infoNOW 89

MODELING AND ANIMATION

3D POWER

WIN Generate stunning 3D Web graphics, 3D flying logos, and architectural walkthroughs, or design game animation sequences using Byte by Byte Corp.'s SoftF/X 3D animation studio. The full-featured modeler and animator program handles large projects with hundreds of objects and lights and hundreds of millions of polygons. More than 50 free plug-ins are currently available. The price is $49.95. (Austin, TX; 512-266-8810; www.byte-bybyte.com)

infoNOW 90

NATURAL IMAGES

WIN From Arete Image Software comes Digital NatureTools for Softimage/3D 3.8, which includes improvements for animating oceans, 3D volumetric clouds, and atmospheric effects with automatic underwater depth-fading capabilities, Mental Ray animating wave bump-map, and enhanced Mental Ray ocean surface shader. Psyclone 1.0 for Maya includes advanced 3D fly-through volumetric clouds, smoke, and other pyroclastic and natural atmospheric effects. Psunami 1.0 for Adobe After Effects enables users to create high-fidelity realistic water effects. The Digital NatureTools for 3D Studio Max plug-in enables the Sisyphus system's Max 2.5 or 3.0 user to integrate detailed water and atmospheric effects with existing scenes, design oceans or clouds, and apply complex ripple and color effects. (Sherman Oaks, CA; 818-501-1045; www.areteis.com)

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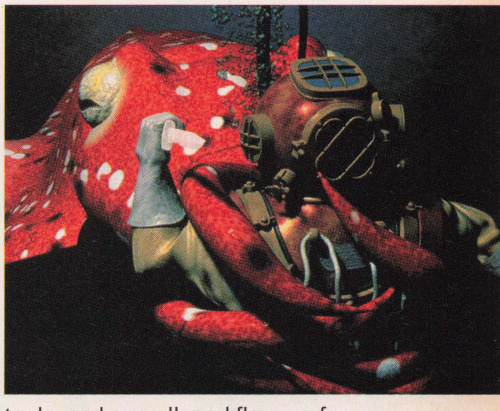
MASTERING ANIMATION

WIN/MAC New to Version 7.1 of Hash Inc.'s Animation Master 99 are advancements in real-time hardware technologies, enhanced rendering



tools, and overall workflow performance enhancements. The software also includes Hash patches, reusable animation libraries, and materials. Joint constraint blending can be used to prevent kinks or creased joints. Additionally, an action created for one character can drive another character

with similar bone hierarchy. The price is $199. (Vancouver, WA; 360-750-0042; www.hash.com)

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WEB 3D

WIN Add real-time 3D interactive experiences to e-commerce, Internet, online entertainment, multimedia products and projects, and games using Shells Interactive's 3D Dreams 2.0 for Director. An intuitive interface is completely integrated with the Macromedia Director environment. A small, downloadable Internet client, the 3D Dreams Player, enables users to interact with the rich 3D content in files no larger than those for standard Web graphics pages. The price is $495. (Brentwood, CA; 310-826-4444; www.doitin3d.com)

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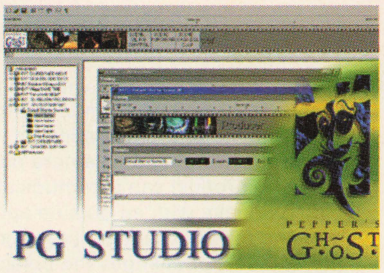
AMBITIOUS ANIMATION

WIN A new production management tool, PG Studio from Pepper's Ghost Productions, offers users a continuous overview of the production elements, accurate control of the schedule, and enhanced ability to deliver completed projects. Users can break down the script and storyboard into scene shots



and frames, providing a systematic structure for production management. The program enables the user to organize production documents according to the script structure, identify production tasks from the script, allocate tasks to creative and technical staff, establish total task time within the schedule, and immediately view the impact of changes to the schedule and budget. (Kingston-upon-Thames, Surrey, UK; +44 0 181 546 4900; www.peppersghost.com)

infoNOW 94

ANIMATION ENGINE

WIN An animation and effects application for Web developers of all skill levels, Emotion 3D: Web Edition from Anark Interactive Media features the AniMesh animation engine, which enables users to create rollover buttons, animated GIFs, and animated 3D clip art with the click of a button. The wizard-style interface clearly defines each step of the process. Additionally, users can apply drop shadows, glows, and outlines to the entire animation, and can manipulate 60 separate behaviors. The price is $69.95. (Boulder, CO; 303-545-2592; www.anark.com)

infoNOW 95

MULTIMEDIA/VIDEO

FLEXIBLE EFFECTS

WIN/MAC Boris FX 4.0 from Artel Software combines standard 3D DVE functionality with sophisticated filter effects, enabling users to generate layered 3D DVE effects within a nonlinear editor "host." This version includes a real-time RAM preview player, a flexible UI with resizable workspace, Bezier animation graphs, drag-and-drop 3D containers for hierarchical 3D DVEs, and drag-and-drop mask containers for masking effects. The price starts at $695. (Boston, MA; 617-451-9900; www.borisfx.com)

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AVID UPDATES

WIN/MAC Planned for release in mid-

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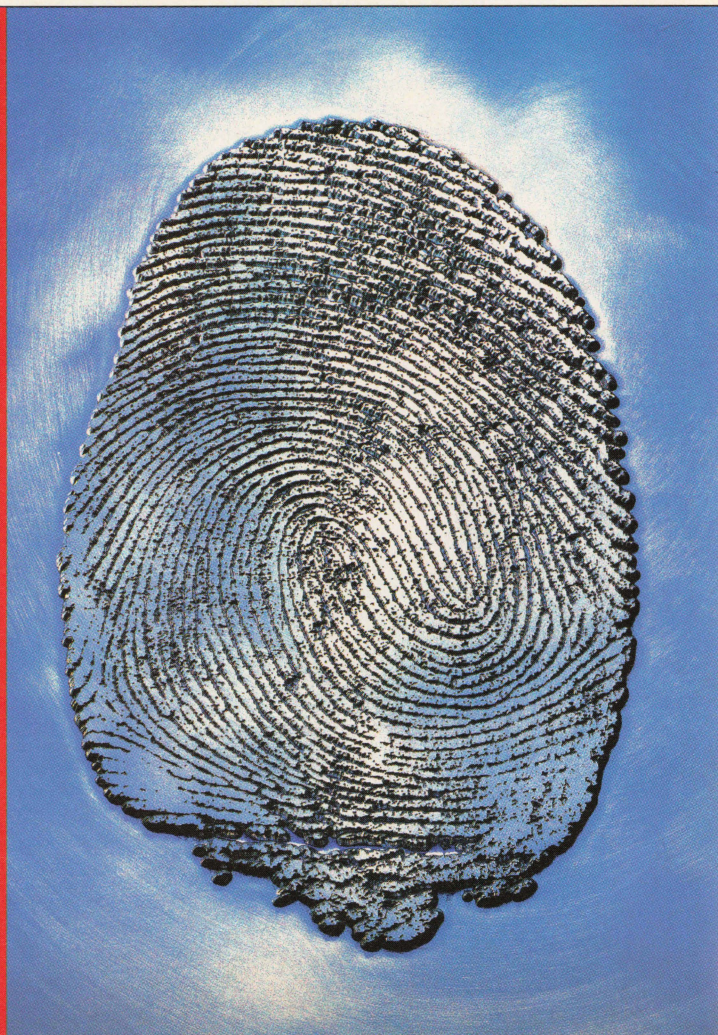

2000, the Millennium Edition of Avid's Media Composer for the Macintosh will include support for the G4 platform, additional AVX plug-ins, and Pan & Scan for video images. Avid and Apple are also collaborating to support Macintosh initiatives, including the joint development of an import/export utility to enable enhanced media sharing between Avid Open Media Framework and Apple QuickTime 4. The company has reduced the price of the Avid Media Composer 9000 ABVB system from $98,880 to $49,400. The cost of a Media Composer 1000 3D has been reduced from $66,000 to $46,100. (Tewksbury, MA; 514-840-0299; www.avid.com)

infoNOW 97

DV EDITING

MAC A paint and special-effects tool for videographers and Web designers, RotoDV from Digital Origin uses QuickTime architecture, enabling it to work alongside other applications and mesh with any multimedia workflow. It ships with a copy of EditDv Unplugged, an entry-level nonlinear editor, as well as a copy of Terran Interactive's Media Cleaner EZ, which enables users to change the video resolution of their projects. Also included is a collection of royalty-free video clip art provided by Dynamic Graphics and Isaacson Communications. The price is $399. (Mountain View, CA; 650-404-6000; www.digitalorigin.com)

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SCIENTIFIC VISUALIZATION

3D VOLUME INTERPRETATION

UNIX The latest version of EarthCube from Landmark Graphics Corp. provides so-called voxbody tracking, stereo viewing, and depth sessions for integrated 3D volume interpretation of large data volumes in complex geological settings. This version also permits voxbody sculpting based on interpreted boundaries, horizons, and faults, enabling the user to examine 3D seismic volume attributes within the context of geologic boundaries. The stereo viewing option enables the interpreter to utilize depth perception to understand complex spatial relationships of various data types. (Houston, TX; 281-649-2941; www.lgc.com)

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HARDWARE

DISPLAYS

FLAT MONITOR

WIN/MAC Using Natural Flat technology, the 17-inch Diamond Pro 710 from Mitsubishi Display Products produces natural-looking flat images that mirror traditional pen and paper imagery. The monitor significantly reduces the effects of ambient lighting, reducing external reflection and glare. It employs a self-convergence system that eliminates compromised corner focus, resulting in better screen performance. The unit has a 0.25mm aperture grille pitch, 30-86kHz horizontal scanning range, and 150MHz video clock frequency. The maximum noninterlaced addressable resolution is 1600x1200 at a refresh rate of 65Hz.The price is $449. (Cypress, CA; 714-220-2500; www.mitsubishi-display.com)

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PROJECTION SYSTEMS

WIN/MAC/UNIX Three SXGA projectors from Digital Projection include one addition to the Power series and two

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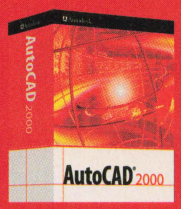

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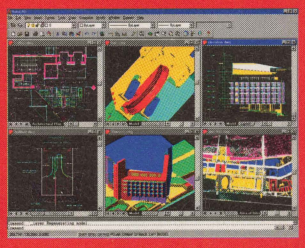

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Lightning series projectors. Also, xenon bubble lamps will be standard in all Lightning displays. The Power 6sx projector ($94,995) integrates the SXGA DMD design and offers more than 5500 ANSI lumens, a pixel fill factor of 92 percent, and a native resolution of 1280x1024. New in the Lightning series, the Lightning 10sx ($109,995) features 10,000 ANSI lumens and the Lightning 15sx ($124,005) features 12,000 ANSI lumens. (Kennesaw, GA; 770-420-1365; www.digitalprojection.com)

infoNOW 101

INPUT/OUTPUT

MOTION TRACKING

WIN Ascension Technology's MotionStar Wireless is a real-time magnetic tracker for animating 3D computer characters. The product enables users to track 20 sensors per performer and uses independent processors for each sensor. Update rates range from 100-144 measurements per second per sensor. DC magnetic tracking technology reduces the metallic distortion associated with AC magnetic devices. The wireless price starts at $60,000, while the wired price

starts at $35,000. (Burlington, VT; 802-893-6657; www.ascension-tech.com)

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DIGITAL CAMERA

WIN/MAC The PhotoPC 800 from Epson America offers a 2.4-megapixel CCD sensor and HyPict image enhancement technology, which provides the ability to print 11- by 14-inch prints. The camera supports both USB and serial image transfer. Other features include an 8MB CompactFlash card, three picture-taking modes, and a high-quality 1.8-inch LCD monitor. According to the manufacturer, users can download a 2-megapixel image in about three seconds. The price is $699. (Torrance, CA; 800-463-7766; www.epson.com)

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HIGH-QUALITY PHOTOGRAPHY

WIN/MAC New from Toshiba Imaging Systems, the PDR-M4 incorporates a 2.14-million-pixel CCD sensor that delivers resolutions to 1600x1200. The unit features USB connectivity in addition to serial output as well as video-out (NTSC) for TV viewing of images. A newly developed DSP chip set extends battery life and speeds the burst rate between shots to enable four shots to be taken in less than two seconds. The price is $699. (Irvine, CA; 800-550-8674; www.dcs.toshiba.com)

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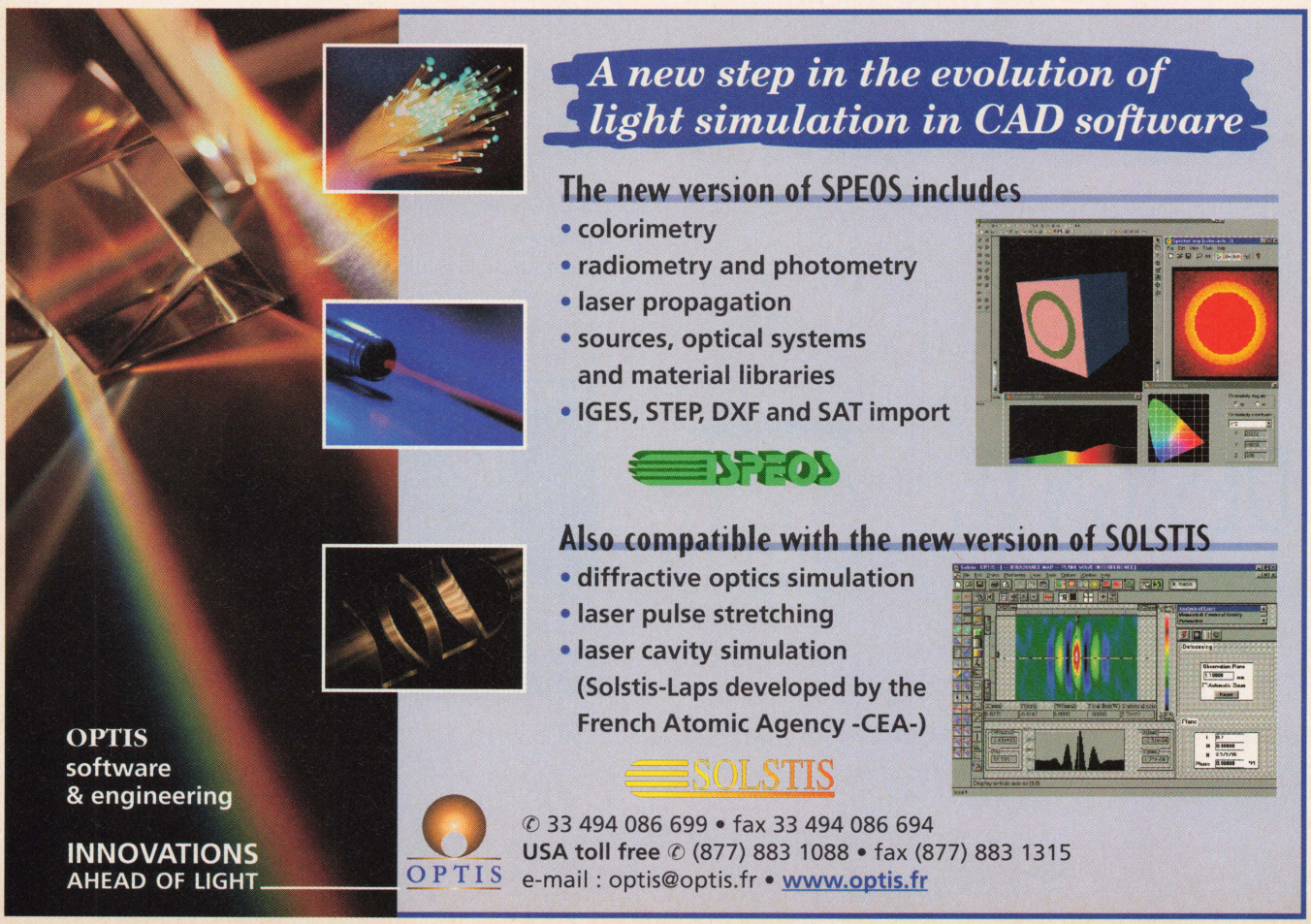

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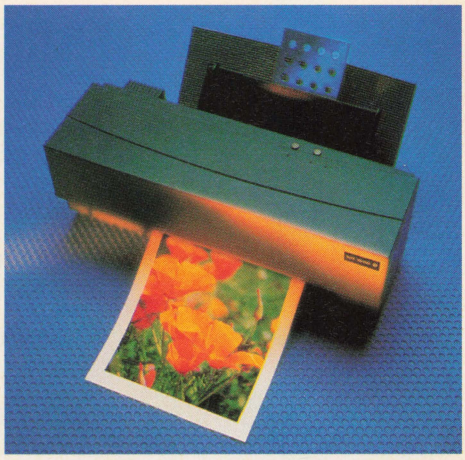

of dot diameter, resulting in superior print quality. The technology combines a thermal controller chip and an ALPS Micro DOS (deposit on silicon) printhead. The fade-proof, waterproof dry inks do not permeate the medium, but rather fix permanently to the surface. The price is $599. (San Jose, CA; 800-825-2566; www.alpsusa.com)

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DIGITAL CINEMA

WIN The Hughes-JVC ILA-12K Cinema projector is based on the Image Light Amplifier (ILA) device. According to the company, liquid-crystal light-valve technology is the key to the unit's ability to exceed 35mm motion-picture film in every area of image quality, on theater-size screens. The unit delivers true, lifelike colors and contrast levels exceeding 1500:1. With more than 12,000 lumens of light output and a display resolution of 2000x1280, the 12K produces a sharp, non-pixelized image with the look of film. (Carlsbad, CA; 760-929-5365; www.hjt.com)

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EVENTS

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12-15 · Spectrum '99, held in Tucson, AZ. Contact: GCA (703-519-8160); (fax: 703-548-2867); www.gca.org

13-16 · Computer Technology Solutions held in conjunction with the Detroit Advanced Productivity Expo (APEX), held in Detroit, MI. Contact: SME (313-271-1500); (fax: 313-271-2861); www.sme.org

22-25 · digiMedia 99, held in Dusseldorf, Germany. Contact: Dusseldorf Trade Shows (312-781-5180); (fax: 312-781-5188); www.dtsusa.com/dts/

29-Oct. 1 · Bentley International User Conference, held in Philadelphia. Contact: Bentley (610-458-5000); www.bentley.com/biuc/register

OCTOBER

13-16 · Association for Graphic Arts Training Annual Conference, held in Schamburg, IL. Contact: Assocation for Graphic Arts Training (800-214-1120); www.napl.org/agat

17-20 · Graph Expo '99/Converting Expo '99, held in Chicago. Contact: Graphic Arts Show (703-264-7200); www.gasc.org

19-22 · Digital Video Conference & Exposition, held in Long Beach, CA. Contact: Miller Freeman Inc. (415-278-5300); (fax: 415-278-5200); www.dvexpo.com

19-23 · Broadcast India '99, held in Mumbai, India. Contact: Saicom Trade Fairs & Exhibitons Pvt. Ltd. (91-22-215-1396); (fax: 91-22-215-1269); www.saicm.com/broadcastindia

NOVEMBER

15-19 · Comdex/Fall '99, held in Las Vegas. Contact: ZD Events (781-433-1805); www.comdex.com

16-18 · Digital Media World, held in London, UK. Contact: Advanstar Communication (+44-1244-399-180); (fax: +44-171-559-9779); www.digmedia.com

DECEMBER

12-13 · Game Developers RoadTrips Conference, held in Boston. Contact: GDC RoadTrips (415-905-2388); (fax: 415-905-2222); www.gdconf.com/rtdm

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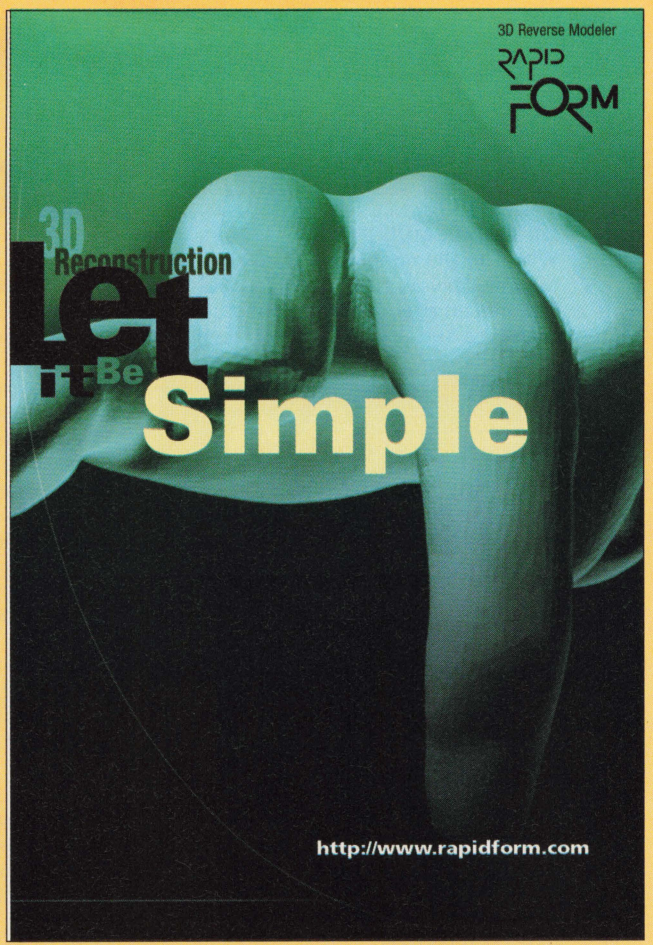

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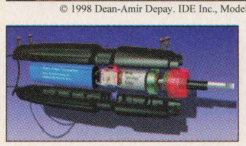
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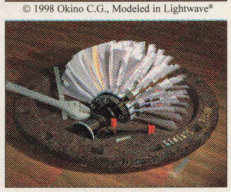
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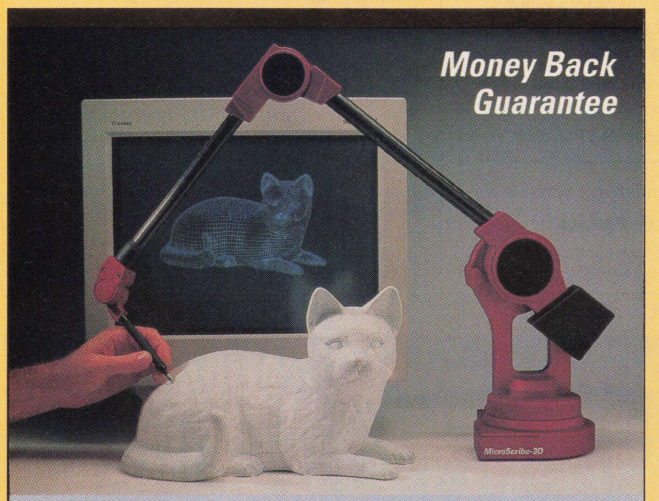

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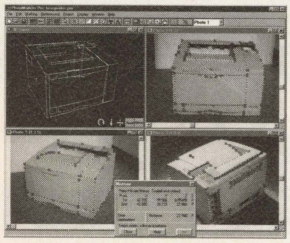

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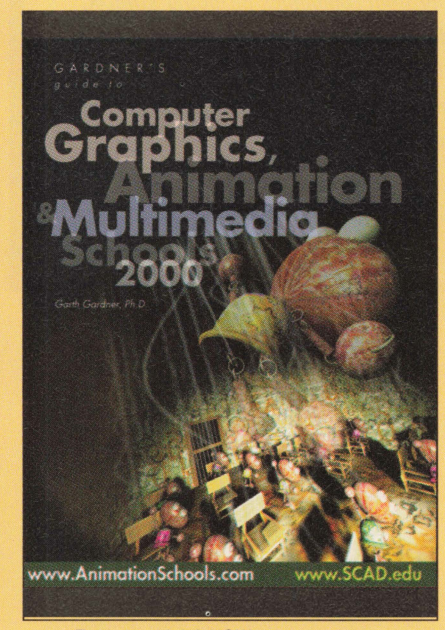

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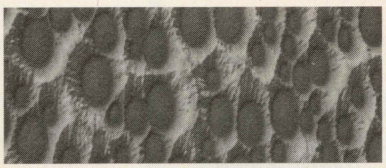

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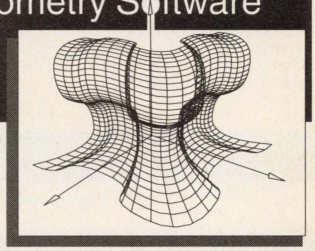

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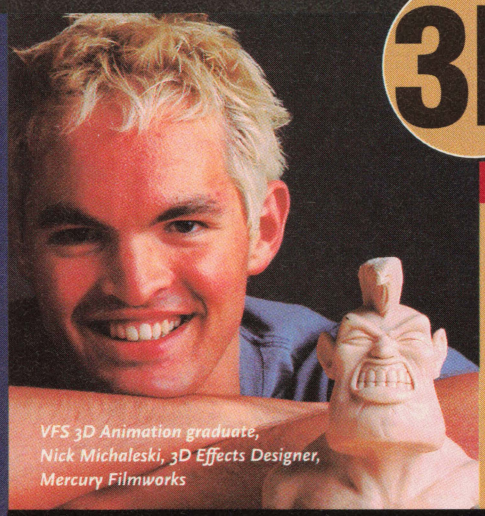

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Research by NCAR scientists Terry Clark and Janice Coen; sponsored by the NSF and US Forest Service. Visualization by Don Middleton, NCAR Scientific Computing Division.

In an effort to observe and understand the dangerous and unpredictable nature of forest fires, scientists at the National Center for Atmospheric Research (NCAR) simulate the phenomena by coupling regional weather data with fire-spread models. Three-dimensional visualization of the numerical results provides a unique window into the fire's behavior. This image depicts the simulation of a forest fire propagating up a hillside, with a westerly wind of about 6 miles per hour. A small fire breaking out on the northern flank rejoins the main firefront, diverting the fire northward. The transparent blue surface surrounding the hot temperature core (red) represents rotation. The green and dark-brown regions depict unburnt and burnt fuel, respectively. —*Diana Phillips Mahoney*

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